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# Charcoal income as a means to a valuable end: Scope and limitations of income from rural charcoal production to alleviate acute multidimensional poverty in Mabalane district, southern Mozambique

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## ABSTRACT

The charcoal industry is among the most important semiformal economic sectors in Sub-Saharan Africa and a key cash income source for local households who produce it. This has intensified the debate as to the role of income from charcoal production in the alleviation of rural poverty. While in a number of cases charcoal production has been identified as a potential alleviator of monetary poverty, this paper takes as its departure point a lack of analysis on the effect of charcoal income on acute multidimensional poverty (AMP). This is understood as the inability of household members to meet minimum national and international standards and core *functionings*. This study used primary data from an important charcoal supplying region in southern Mozambique (N = 312). The Alkire-Foster method was used to aggregate AMP in nine composite indicators. Generalised linear models were used to assess the marginal effect of charcoal income on AMP, controlling for other determinants. Our findings show a high intensity (67.7%) and prevalence of AMP (0.429) in the study area (n = 261). 59% of the identified non-monetary poor from charcoal making are identified as acute multidimensionally poor. Charcoal income is found to be positively correlated with valuable household assets, and charcoal production increases the resistance to impoverishment in certain circumstances. However, charcoal income was not found to be a statistically significant determinant of AMP, even for the most productive charcoal makers. This highlights the enormous barriers both producers and non-producers of charcoal alike face in this region in order to overcome AMP. Our findings thus challenge the perception that charcoal income can sufficiently alleviate poverty, particularly when a multidimensional perspective is adopted. Reductions and eventual eliminations of AMP require a concentrated cross-sectional whole-of-government approach to tackle poverty in its multidimensional breadth and complexity, while attempts at making the charcoal industry more inclusive and equitable should be accelerated.

## 1. Introduction

Charcoal is one of the most important domestic fuels used in Sub-Saharan Africa (SSA) (Butz, 2013; Girard, 2002). Charcoal is a popular woodfuel, particularly with urban consumers because of its clean and even burn (Jones, Ryan, & Fisher, 2016), and because it is affordable (Iiyama et al., 2015). Due to population growth and urbanisation it is projected that demand for charcoal will increase substantially until 2030 (World Bank, 2011). In consequence, the charcoal sector offers employment to millions of people and thus fulfils an increasingly important role for the economic

development of many countries in SSA (IAE, 2014; Ndegwa, Anhof, Nehren, Ghilardi, & Liyama, 2016). In Mozambique for instance, it is estimated that up to 3 million people (approx. 15% of the population) are involved in the semi-legalised (yet mostly informal) charcoal trade (Cuvilas, Jirjis, & Lucas, 2010), with an estimated value equivalent of 2.2% of Mozambique's GDP (Van der Plas et al., 2012). In Kenya, the charcoal industry was estimated as the fourth biggest economic sector (Njenga et al., 2013) whose estimated market value paralleled in size to that of the tea industry (Mutimba & Barasa, 2005), while in Malawi it paralleled the tobacco and sugar industries (Kambewa, Mataya, Sichinga, & Johnson, 2007).

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The economic importance of the charcoal sector in most countries in SSA accelerated research efforts to analyse the role locally produced charcoal has on rural poverty. Most people engaged in the woodfuel market are rurally based (Openshaw, 2010) in the role of small-scale “casual” producers or transporters (Zulu & Richardson, 2013; Baumert et al., 2016), where producers have a viable opportunity to supplement income from other livelihood activities (Jones et al., 2016; Levy & Kaufman, 2014). Studies then differ in their assessment of the role of charcoal in poverty alleviation.<sup>1</sup> Studies found charcoal producers to be economically better off (Ainembabazi, Shively, & Angelsen, 2014; Schure, Levang, & Wiersum, 2014), with welfare benefits from charcoal making that contribute to poverty reduction (Fisher, 2004; Schure et al., 2014; Yemiru, Roos, Campbell, & Bohlin, 2010). The welfare benefits were found in some cases to be enough to lift certain groups of producers above the poverty line (Ainembabazi et al., 2014; Shackleton, Shackleton, Buiten, & Bird, 2007) which meant charcoal can be identified as a potential pathway or route out of poverty. This intensified calls for improved formalisations of the charcoal industry (Jones et al., 2016; Schure, Ingram, Sakho-Jimbira, Levang, & Wiersum, 2013; Schure et al., 2014; Smith, Eigenbrod, Kafumbata, Hudson, & Schreckenberg, 2015).

Although economically better-off, and moving closer to the poverty line, some studies though found that the average charcoal producer continues to live below the poverty line (Schure et al., 2014: S85). Consequently, some studies rather identified charcoal cash income as a coping strategy (Kalaba, Quinn, & Dougill, 2013; Kambewa et al., 2007) or a safety net (Arnold, Köhlin, & Persson, 2006; Bekele & Girmay, 2014; Djoudi, Vergles, Blackie, Koame, & Gautier, 2015; Zulu & Richardson, 2013), where, for instance, charcoal producing households increase their resistance to idiosyncratic shocks by accumulating household savings. While unable to lift people out of poverty, charcoal cash income was found to contribute to the prevention and mitigation of poverty (Khundi, Jagger, Shively, & Sserunkuma, 2011). For some subgroups of producers however, particularly for the chronic poor (Hulme & Shepherd, 2003) and the severely poor (Ravallion, 1998), charcoal production was found to be a poverty trap (Angelsen & Wunder, 2003; Ndegwa et al., 2016). These subgroups are characterised by an over-reliance on charcoal as a livelihood strategy, and little opportunity to expand their production or diversify into alternative livelihood activities. Returns are used to meet basic subsistence needs.

The predominantly monetary focus deployed in the studies reflect the entrenchment of the discussion in welfare and environmental economics as well as livelihood analyses. Charcoal is one of the most important “environmental income” sources across developing countries (Angelsen et al., 2014) and the academic debate on the role/contribution of charcoal income to wealth accumulation (Ndegwa et al., 2016), livelihood diversification (Jones et al., 2016; Schure et al., 2014; Smith, Hudson, & Schreckenberg, 2017; Zulu & Richardson, 2013), and the absolute *vis-à-vis* relative dependence of different income quintiles on environmental incomes (Angelsen et al., 2014; Kamanga, Vedeld, & Sjaastad, 2009; Levy & Kaufman, 2014; Ndegwa et al., 2016) is rich.

<sup>1</sup> The empirically most applied poverty conceptualisation in the reviewed literature is by Angelsen and Wunder (2003: 2), whereby poverty alleviation encompasses both reductions in poverty and poverty preventions. Poverty alleviations are thus achieved if the poor obtain welfare benefits (e.g. from charcoal making) that allows them to move closer to the poverty line (becoming better-off), and ideally move above the poverty line, or prevents them from moving into poverty, or deeper into poverty. Other definitions found in the literature are similarly encompassing (e.g. Sunderlin et al., 2005: 1386); yet Sunderlin et al. replaces poverty reduction with poverty elimination. While poverty reduction may encompass becoming better-off, without necessarily leaving poverty, eliminating poverty necessitates leaving poverty, even if it is only temporarily. In this paper, the understanding of poverty alleviation is closer to Sunderlin et al. in that we do not analyse the depth and severity of poverty, but rather focus on the question of whether charcoal contributes to the elimination and prevention of acute multidimensional poverty. Whether charcoal helps reducing poverty (e.g. becoming better-off by moving from severe poverty status closer to the poverty line) is subject of analysis of another paper.

Yet the focus on income poverty and the derived welfare benefits from charcoal making also masks an important question: what is the contribution of income from charcoal production to the alleviation of acute multidimensional poverty? That is understood as the inability of household members to meet minimum national and international standards and core *functionings* (or achievements, such as access to clean drinking water and sanitation, see Alkire & Santos, 2010a, 2010b, 2014). Charcoal is a woodfuel and thus a forest provisioning ecosystem service (MEA, 2005; Kalaba et al., 2013). A systematic review of the empirical links between provisioning ecosystem services and poverty found a lack of analysis of multidimensional poverty (Suich, Howe, & Mace, 2015).<sup>2</sup> While most charcoal studies do analyse possible spill-over effects of charcoal cash income onto key indicators of human development – e.g. Ndegwa et al. compare the education of household heads of non-producers versus producers of different charcoal production scales (2016: 172) and Schure analyses spending patterns of charcoal income on education and healthcare – the selection of indicators used is selective and usually in a dashboard (where indicators are analysed separately from each other (see Alkire et al., 2015)). To our knowledge no charcoal analysis has used aggregated household data to systematically account for what is known as the *breadth of poverty* (Alkire et al., 2015): the empirical observation of simultaneous (joint) deprivations in key dimensions of well-being such as education, health or standard of living that have low inter-correlation and cut across the human, social and economic capital of the poor (Alkire & Foster, 2007).

In light of this research gap, the objective of this paper is to investigate the impact of rural charcoal production on the alleviation of acute multidimensional poverty, understood as both the prevention and eventual elimination of poverty (Sunderlin et al., 2005). Studies that analyse multidimensional poverty and their determinants are deployed more frequently in development and social economics (Ataguba, Ichoku, & Fonta, 2013; Mahoozi, 2016; Reeves, Rodrigue, & Kneebone, 2016; Santos, Dabus, & Delbianco, 2016; Wang, Feng, Xia, & Alkire, 2016). Such studies offer methodologically viable analyses of the now widely held view that poverty is a multidimensional phenomenon (as acknowledged as target 1.2 of the Sustainable Development Goals (SDGs) by the United Nations). We argue that the academic debate about the role of charcoal income on poverty alleviation is incomplete unless the instrumental value of charcoal income is systematically assessed as a means to a valuable end. That is, what is the contribution of charcoal income to the achievement of what is known as *functionings* that people have identified and have reason to value (Alkire & Santos, 2014; Sen, 1992; Sen, 1999).

We consider Mozambique an illuminating case study to investigate the impact of local charcoal production on acute multidimensional poverty. Firstly, the country typifies the challenge of managing mopane woodlands, the dominant vegetation type in southern Africa (White, 1983), for the benefit of the rural poor. While the country still has an extensive woodland resource (70% of the land cover; 55 M ha), rates of deforestation (0.2–1.7%/yr (Marzoli, 2007)) and degradation are high (2–3%/yr (Ryan et al., 2011)). Studies suggest that the rural poor are disproportionately disadvantaged by the woodland loss (see Baumert et al., 2016a; Baumert et al., 2016b; Woollen et al., 2016). The National Forest Directorate under the Ministry of Land, Environment and Rural Development uses a forests programme (*Floresta em Pé* (Standing forests)) under its flagship development program (*Programa Nacional Integrado de Desenvolvimento Rural Sustentável (Estrela)*) that aims to achieve that the sustainable use of forest resources is contributing to the alleviation of rural poverty (CGMC, 2015; Connect4Climate, 2015). The

<sup>2</sup> Suich et al. reviewed 398 refereed studies published from the year 2000 onwards on the empirical links between ecosystem services and poverty, and found that poverty was assessed at most in two dimensions of poverty, either relating to income/assets or food security/nutrition. Many studies were found to focus “only on income, rather than taking a multidimensional approach to poverty” (2015: 137–138).

inclusive and community-based usage of natural resources is also a key priority area in the government's current five year plan 2015–2019 (GoM, 2015). Secondly, the Government of Mozambique adopted a multidimensional definition of poverty in 2011 (MPD, 2011) and continues to monitor poverty both in the monetary and non-monetary space (MPD & DNEAP, 2010; MEF, 2016). We consider this to be a fruitful policy environment for a study that assesses the scope and limitations of charcoal income to multidimensional poverty alleviation.

As part of an interdisciplinary project entitled Abrupt Changes in Ecosystem Services and Wellbeing in Mozambican Woodlands (ACES) that assesses the impacts of woodland degradation on rural poverty, we purposefully collected data in an important charcoal supplying region in southern Mozambique, in order to identify and aggregate *acute multidimensional poverty* (subsequently referred to as AMP, which is also used to abbreviate the *acute multidimensionally poor*), and to study the contribution from charcoal income to its alleviation. Based on established differences between income and multidimensional poverty found elsewhere in the literature – e.g. Wang et al. identified that 69% of the multidimensional poor in China are not considered to be in income poverty (2016)<sup>3</sup> – as well as emerging research findings that thus far suggest that the elasticity of multidimensional poverty to economic growth is low (Mahoozi, 2016) or respectively lower in comparison to the elasticity of income poverty (Santos et al., 2016), we hypothesise that cash income from charcoal production is not sufficient for the alleviation of AMP.

## 2. Methods

### 2.1. Description of study site and village selection

Data collection took place in May–October 2014 in Mabalane district, Gaza province, in southern Mozambique, approximately 300 km north of Maputo (see Fig. 1).

The area is a semi-arid region (annual rainfall of under 500 mm (FEWSNET, 2011)) that is prone to frequently occurring hazards including droughts and frequent storms (OCHA, 2016). The district is relatively sparsely populated with 5329 households recorded in the Census 2007 (INE, 2007), and a population density of 3.6 persons km<sup>-2</sup> (INE, 2008). It is characterised by little market access to the southern commercial centres Chokwe, Xai-Xai and Maputo. Dirt roads that connect the villages are often impassable during the wet season (Woollen et al., 2016). While the district capital *Mabalane-sede* is connected to the electric grid, most villages of the district are not (GENI, 2016).

The study area was identified as a production stronghold in the regional charcoal trade supplying the capital Maputo. According to Mozambique's Forest and Wildlife Law (GoM, 1999), any commercial woodland extraction needs authorization through a licence (*contrato de exploração*) which is available to national operators and local communities for 5 years (Baumert et al., 2016a). Mabalane district has the highest licensed charcoal production in Gaza province, the province with the highest number of charcoal licences throughout the country (Luz et al., 2015).

Following the end of Mozambique's civil war (1997–1992), villagers returned to their home villages and started to produce charcoal on a small-scale to supplement their subsistence income from smallholder agro-pastoralism (Levy & Kaufman, 2014; Levy, Webster, & Kaufmann, 2012). According to local forest officers, charcoal production started to accelerate in the mid-2000s when more licences were granted to exploit local forests. However, villagers were found to be excluded as most charcoal was produced by migrant workers from the neighbouring province Inhambane under licences held by commercial operators residing in the capital Maputo (Baumert et al., 2016a, 2016b).

Based on detailed village histories and key informant interviews, seven small rural villages were selected for the study. The villages displayed, as far as possible, similar soil and vegetation types. Participatory land use mapping exercises were utilised to obtain individual village boundaries (see Table 1).

### 2.2. Data collection methods

A household list was compiled based on a household definition of people who “eat from the same pot” (ORGUT, AustralCOWI, & Chr. Michelsen Institute, 2012). Households were then randomly selected for a socio-economic household survey ( $n = 261$ ). Households were questioned on their socio-economic and demographic characteristics for the reference year 2013–2014. The survey was conducted on tablets with six trained enumerators using Open Data Kit software (Brunette et al., 2013). The final sample obtained can be considered an “incomplete census” (Dodge, 2003) of our study area (84%). In parallel we ran participatory rural appraisals (PRAs) (Chambers, 1994) to obtain qualitative data in order to a) identify locally relevant parameters of AMP, and b) to study the functional relationships of AMP with demographic and socio-economic characteristics of local households. Poverty focus group discussions and participatory wealth rankings were utilised (they are outlined in greater detail in S11).

### 2.3. Identifying and analysing charcoal producers

Charcoal producers were classified by charcoal income quintiles (with mean values  $\pm$  standard errors given if not indicated otherwise). Descriptive statistics of households producing charcoal are shown, and livelihood strategies in our study area are described. They were classified into different income categories as popularised by the Poverty Environment Network, where categories range from direct and processed forest income over income from agro-pastoralism, to non-environmental income from businesses or wage labour (Angelsen, Larsen, Lund, Smith-Hall, & Wunder, 2011; CIFOR, 2008). Producers of charcoal above the mean and median production of charcoal are then depicted. The corresponding income distribution from charcoal making is portrayed with the Lorenz curve (Atkinson, 1970) and the Gini coefficient (Gini, 1914) in order to understand the level of income inequality from charcoal making in the study site. Income quintiles were then analysed, *ceteris paribus*, with regard to their extreme (monetary) poverty status. The notion is to explore whether the non-extreme poor are also out of AMP (2.4), and if so, to analyse whether charcoal production can be attributed to this effect (2.5).

### 2.4. Identifying and aggregating the acute multidimensional poor

The theoretical premise to assess poverty in the multidimensional sense, and thus beyond a narrow money-metric assessment, is grounded in Mozambique's official understanding of poverty as a multidimensional phenomenon, as defined in the third Poverty Reduction Action Plan 2011–2014 (“Poverty is a multidimensional phenomenon, and combating poverty goes well beyond a simple discussion of the underlying characteristics of absolute poverty” (MPD, 2011)) and the Government of Mozambique's five year government plan 2015–2019 (GoM, 2015). Empirically, various multi-stakeholder focus group discussions on poverty deployed at national (Maputo), provincial (Xai-Xai) and at village level for this study established a strong link to non-monetary dimensions of poverty, particularly with *functionings*, such as food security, or having access to clean drinking water (see Table 1, S11).

The Alkire-Foster (AF) method (Alkire & Foster, 2007; Alkire & Foster, 2011a) was then used to identify and aggregate AMP. The method was chosen due to its axiomatic and decomposable features; its accounting for the breadth of poverty not captured in dashboard and other estimates of multidimensional poverty (Alkire et al., 2015:

<sup>3</sup> For similar findings see Alkire et al. (2015), Ataguba et al. (2013), Castro, Baca, and Ocampo (2012), Ruggeri-Laderchi, Saith, and Stewart (2003).



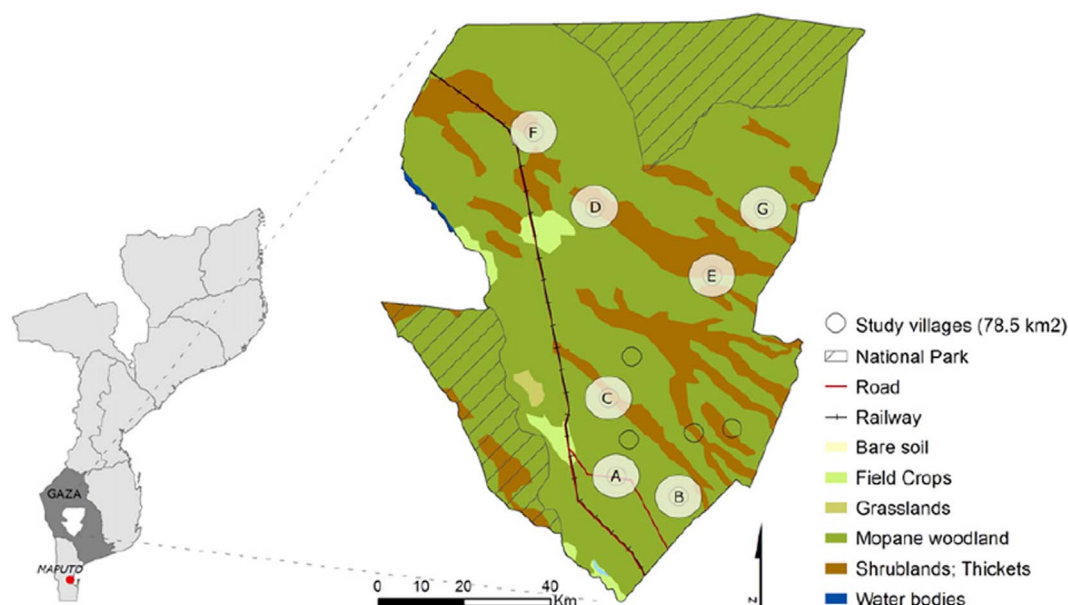


Fig. 1. Land cover and study villages (A–G) in Mabalane district, Gaza province, southern Mozambique (Woollen et al., 2016). Village names are abbreviated. A = Matlantimbuti; B = Sangue; C = Tindzwaene; D = Mavumbuque; E = Mabuapense; F = Hochane; G = Matchele.

**Table 1**  
Village selection and their main characteristics. Mabalane district, Gaza province.

Village	Matl A	San B	Tins C	Mav D	Mabu E	Hoch F	Match G	Total
Number of households (HH) in village (N)	38	29	63	42	58	55	27	312
HH sampled (n)	35	25	51	36	42	48	24	261
(% of N)	(92)	(86)	(81)	(86)	(72)	(87)	(89)	(84)
Households (HH) producing charcoal (% of n)	29	23	46	22	21	42	0	183
	(83)	(92)	(90)	(61)	(50)	(88)	(0)	(70)

All data refer to 2013–2014. –: no observation. N: village population. n: sample size. Village names are abbreviated. Matl A = Matlantimbuti; San B = Sangue; Tins C = Tindzwaene; Mav D = Mavumbuque; Mabu E = Mabuapense; Hoch F = Hochane; Match G = Matchele.

70–123); its methodological robustness (see Alkire & Santos, 2014; Alkire et al., 2015: 233–256); and its overall growing popularity as a scientific supplement to monetary measures of poverty (as it is a direct rather than indirect measure of poverty (Alkire & Santos, 2014: 251)).<sup>4</sup> The measure relies on *empirical observations* of actual achievements (or the lack thereof) in key dimensions of poverty, and is thus less prone to prediction errors as often found with monetary poverty estimates that rely on imputation methods (Gaddis & Klasen, 2012). It allows for a clear mapping of the multidimensional poor, decomposed by village and poverty dimension. Thus, a “high-resolution lens” of the acute multidimensional poor (Alkire & Santos, 2010a: 1) in the study area is given.

Conceptually, the AF-Method is broken into the selection of an identification function  $\rho$  and an aggregation step. The identification function comprises the choice of the unit of analysis  $n$ , of relevant dimensions  $d$  and indicators  $j$  of AMP, an indicator specific  $z_j$  and cross-dimensional specific cutoff line  $k$  (which can range from  $k = 1$  (known as “union approach”) to  $k = d$  (known as “intersection approach”)), as well as respective weights across indicators  $w_j$ . We utilised a sequenced mixed methods approach (see Hulme, 2007; Shaffer, 2013) to identify  $\rho$ . Results from poverty focus group discussions were triangulated with participatory wealth rankings results and a structured secondary

literature review. Table 2 presents the identification of dimensions  $d$ , respective indicators  $j$ , indicator specific cutoff lines  $z_j$  and weights  $w_j$  used to aggregate AMP<sup>5</sup> (we present the process that led to the identification of  $\rho$ , as well as descriptive statistics for each selected indicator  $j$ , in great detail in S11). AMP is assessed in nine (composite) indicators, all of which are ordinal, grouped along three dimensions (namely human, social and economic capital). The function is then represented as  $\rho: R_+^d \times R_+^d \rightarrow \{0,1\}$ , that denotes a person's  $i$ 's achievement vector  $y_i \in R_+^d$  and cutoff vector  $z$  in  $R_+^d$ . A household  $n$  is considered to be AMP if and only if a household's weighted deprivation count  $c_i$  is equal to or greater than  $k$  ( $c_i \geq k$ ), and is then given the value of  $Y_i = \rho(y_i; z) = 1$ , and 0 if otherwise. In this study, the cross-dimensional cutoff line was set at  $k = 4$ , which means that a household is in AMP if

<sup>5</sup> Following Alkire et al. (2015) and Alkire and Santos (2014: 253), indicators were chosen to represent as accurately and yet parsimoniously as possible the respective poverty dimension, without displaying a high intercorrelation (Cronbach  $\alpha = 0.4$ ). Also, wherever possible and logically coherent, indicators were chosen that feature in the Multidimensional Poverty Index (MPI) in order to increase comparability of our research findings (Alkire & Santos, 2010a, 2010b, 2014; Alkire et al., 2016). Indicator specific cutoff lines  $z_j$  were chosen according to international standards or through inductive reasoning. Overall, indicators were chosen that are susceptible to pro-poor policy prescriptions (e.g. access to equitable health care is improvable upon increasing the physical availability, social acceptability and financial affordability of health care). Most indicators are outcome/achievement indicators (*functionings*), e.g. in relation to formal education, while some are opportunity/input indicators (e.g. access to services, associations and credit).

<sup>4</sup> Refer to Ravallion (2011) for a critique on composite indices on multidimensional poverty. For a response on the critique, see Alkire and Foster (2011b).

**Table 2**

List of Acute Multidimensional Poverty dimensions, indicators, cut-off lines and weightings used to identify the poor in the study region, Mabalane District.

Dimensions (d)	Indicators (j)	Deprived if... (z <sub>j</sub> )	Nested weighting (w <sub>j</sub> ) scale (%)
Human capital	1. Sanitation	1. The household's sanitation facility is not improved (according to the MDG guidelines), or it is improved but shared with other households <sup>*1</sup>	0.66 (6.7)
	2. Water	2. The household does not have yearlong access to clean drinking water (according to the MDG guidelines) or clean water is more than 30 min walking from home (roundtrip) <sup>*1</sup>	0.66 (6.7)
	3. Under-five mortality	3. Any child has died in the household (in the past 12 months) <sup>*2</sup>	0.66 (6.7)
	4. Access to equitable health care	4. The household does not have access to equitable health care	0.66 (6.7)
	5. Formal Education (illiteracy, highest qualification achieved)	5. No household member is able to read and write and achieved at a minimum grades 1–5 of a primary education degree or attended the Portuguese colonial school system <sup>*2</sup>	0.66 (6.7)
Social capital	1. Food (in)security	1. The household experienced a food shortage in the past	1.665 (16.6)
	2. Access to services, associations and credit	2. The household did not receive advice from an extension agent during the last 12 months, and did not receive a credit in the last 12 months, and is currently not a member in an agricultural or forestry association	1.665 (16.6)
Economic capital	1. Assets owned	The household does not own a motorbike, truck, car, cart, cassette/dvd player, bed or chainsaw, or does not own more than one radio, television, telephone, refrigerator or bicycle <sup>*2</sup>	1.665 (16.6)
	2. Housing (floor, roof, walls)	The household has sand or smoothed mud floor, and grass or poles roof, and sand, mud, grass or poles walls <sup>*2</sup>	1.665 (16.6)

Note: <sup>\*1</sup> marks selection of z<sub>j</sub> based on the Multidimensional Poverty Index MPI (Alkire & Santos, 2010b; Alkire et al., 2016); <sup>\*2</sup> marks selection of z<sub>j</sub> derived from MPI (Alkire & Santos, 2010b; Alkire et al., 2016).

the sum of weighted indicators in which a household is deprived amounts to at least 44.4% (thus if a household is deprived in *at least* three indicators *across* two dimensions).<sup>6</sup> A nested weighting structure w<sub>j</sub> was chosen that gives each of the three dimensions of AMP the same weight.

Data on the household's poverty status were then aggregated into two different classes of AMP at the village level, namely the headcount ratio *H* (reported in percentage) and the adjusted headcount ratio *M*<sub>0</sub> (reported as a value). The headcount ratio *H* reports the incidence of AMP ( $H = \frac{q}{n}$ , where *q* are households identified as AMP divided by total number of households *n*), whereas the breadth-adjusted headcount ratio *M*<sub>0</sub> reports the prevalence of poverty, by which the (weighted) number of dimensions in which each household is deprived are added into *H*; thus, it calculates into *H* the average intensity of poverty  $A = \sum_{i=1}^n c_j \frac{k}{q}$ . *M*<sub>0</sub> satisfies dimensional monotonicity, by which societies, under equal incidences of poverty (*H*), are considered poorer whose intensity of poverty (*A*) is greater (in other words, if a poor person becomes additionally deprived in an additional dimension of poverty, the intensity of poverty increases, as does the breadth-adjusted headcount ratio). For a full account of the measurement's properties and mathematical structure, see Alkire and Foster (2007, 2011a).

First and second-order stochastic dominance tests, rank robustness analyses and statistical inference tests were applied to ensure that the obtained poverty rankings were robust to changes in key parameters of the identification function  $\rho$ . Core findings of this process are presented, while S12 contains the detailed presentation of the test results. S12 also contains comparative poverty measures (Table 2 in S12) that place the calculated headcount ratio *H* in Mabalane next to Mozambique's official poverty headcount *H*, the poor that are classified based on the international US\$1.25/day and US\$2.5/day measure (and the adjusted US\$1.90/day and US\$3.10/day measure), as well as poverty headcount calculated for the Multidimensional Poverty Index for Mozambique.

<sup>6</sup> In contrast, the MPI (Alkire & Santos, 2010b; Alkire et al., 2016) sets *k* at 33.3%, meaning that at a minimum, a person could be labelled multidimensional poor if it is deprived in all six indicators of their dimension "standard of living" alone (please see S11 for more information). In other words, at a minimum, the MPI defines multidimensionality at indicator level, whereas in this case study, at a minimum, we define multidimensionality both at indicator and dimension level. In addition to being identified as acute multidimensional poor ( $c_i \geq k$  Alkire et al. also introduced the "vulnerable to poverty" category, and the in "severe poverty" category in later editions of the MPI first launched in 2010. Those vulnerable to poverty are deprived in 20%–33.3% of weighted indicators, whereas the severe poor are deprived in 50% or more indicators (2016: 7–8).

## 2.5. Determining the marginal effect of charcoal production on AMP

Households identified as AMP ( $Y_i = \rho(y_i; z) = 1$ ) were placed next to their calculated income quintile from charcoal making (Chart 8). Two Generalised Linear Models were then used to predict probabilities that *Y*<sub>*i*</sub> takes the value of one given the use of socio-economic and demographic predictors. Regression analysis at the micro (household) level was chosen as it is considered the most efficient way to answer the research question of whether charcoal income leads to deductions in the likelihood of being acute multidimensional poor, while controlling for reasonable alternative determinants. Following Alkire et al. (2015: 306ff) we specified a Bernoulli distribution to model the conditional distribution  $p_{Y_i}(y_i) = \pi_i^{y_i}(1-\pi_i) \times 0 = \pi_i$  with a logit link function that ensures that the conditional mean given by the conditional probability  $\mu_{y_i|x_i} = \pi_i \times 1 + (1-\pi_i) \times 0 = \pi_i$  stays between zero and one. We specified

$$\log_e \frac{\pi}{1-\pi} = \beta_0 + \beta_1 x_{1i} + \dots + \beta_K x_{Ki} \quad (2.1)$$

$$\text{with } \frac{\pi}{1-\pi} = e^{\beta_0} (e^{\beta_1})^{x_{1i}} \dots (e^{\beta_K})^{x_{Ki}} \quad (2.2)$$

where the logit of  $\pi$  is the natural logarithm of the odds that the binary variable *Y*<sub>*i*</sub> takes the value of one. The partial regression coefficients  $\beta_j$  are interpreted as the marginal changes of the logit due to a one unit increase in *x*<sub>*j*</sub>, and  $e^{\beta_j}$  as the multiplicative effect on the odds of increasing *x*<sub>*j*</sub> by one, holding the other predictors *K* constant.  $e^{\beta_j}$  is reported as the "odds ratio" in the models, whereas  $\beta_j$  is reported as the "parameter estimates" whose sign (positive or negative) shows increases or deductions in the odds of being multidimensionally poor ((1-odds-ratio) × 100)). Corresponding standard errors, *z* statistics, and significance levels at 5% are shown.

Two models were specified in that manner with a maximum of eleven predictors. The selection of predictors was based on an empirical-theoretical process. Firstly, we chose variables with explanatory power that were not used in the construction of the AMP measure (this was done to circumvent a potential endogeneity problem in the models (see Alkire et al., 2015: 297)).<sup>7</sup> Secondly, we chose indicators that were empirically named as factors in the placement of households in the

<sup>7</sup> Usually, these predictors are expected to be uncorrelated with the error term of the models in order to circumvent a potential endogeneity problem (see Alkire et al., 2015: 297), yet the specified Bernoulli distribution applied in this paper does not contain an error distribution independent of the predictor values as the random distribution is attributed to the dependent variable itself (see Alkire et al., 2015: 301).

different wealth clusters (as established via the participatory wealth rankings, a relative poverty measure where the households were classified from poorest (1) to best-off (4), see Table 2 in SI1). The focal explanatory variable is income from charcoal making (see Fig. 1 in SI1, where charcoal was the single most cited explanatory variable for placements of households in the different wealth categories (mentioned 31 times)); but given that the chosen unit of analysis was the household, members of labouring age were found to engage in several livelihood activities (where, for instance, men were engaged in charcoal production, women in smallholdings and adolescents in animal husbandry, among other activities (see analysis of placement into different wealth clusters in SI1)). Thus other indicators of concern were also identified, such as the size of the managed farmland (which was mentioned 29 times during the wealth rankings), the holdings of livestock,<sup>8</sup> the composition of household members in labour age, the livelihood diversification or a household's subjective perception of fortune.

As these covariates explain relative wealth based clusters but insufficiently explain multidimensional poverty, we also incorporated variables found to hold relevance in similar applications of multivariate analyses into determinants of *multidimensional poverty*, such as status of residency, vulnerability to shocks, or gender of household head (see Alkire et al., 2015; Betti, D'Agostino, & Neri, 2003; D'Ambrosio, Deutsch, & Silber, 2011: 306ff). A number of potential predictors often applied in monetary poverty regressions were excluded due to endogeneity concerns (i.e. indicators in relation to education or health status of household members).

A series of regression estimation diagnostics (UCLA, 2016) were undertaken to ensure the statistical goodness of fit of our model specifications, particularly of the first model that contains all eleven covariates and thus is the more comprehensible model.<sup>9</sup> Given different sample sizes at the village level, model specifications were oriented at the  $n/k > 15$  rule, where  $n$  is the number of observations (that also tend to vary due to missing data) and  $k$  is the potential number of

<sup>8</sup> Cumulatively, pastoralism was the most named covariate for placement in different wealth categories (comprised of cattle and cows (named 34 times), chicken (10), goats (8) and other livestock (6)).

<sup>9</sup> The analysis initially comprised fifteen (non-indicator measurement) predictors (subsequently referred to model B), which were reduced in the post-estimation diagnostics to eleven demographic and socioeconomic predictors (subsequently referred to as model A). The additional indicators were “net value of livestock”, “age of household head”, “household size” and a dummy variable taking a value of one if the household did report to have been in “wage labour” and 0 if it did not. The diagnostics comprised a correlation analysis via Cronbach  $\alpha$ ; a Hosmer-Lemeshow goodness of fit test (where a scaled deviance statistic  $D^*(y;\hat{\mu}) = 2l(y;\hat{\mu}_{(a)}) - 2l(y;\hat{\mu}_{(b)})$  is twice the difference between the maximum log likelihood of the parsimonious model A and the comprehensive model B. A Hosmer-Lemeshow  $\chi^2_{df}$  with df as. degrees of freedom is applied to test the null hypothesis  $H_0$  that model A is as good a fit as model B (known as the *parsimony* rule); the variance inflation factor to quantify severity of multicollinearity; a Pearson, deviance and Pregibon residual analysis; a specification error detection with a linktest; a Receiver operating characteristic (ROC) curve; and a Wald statistic of parameter constraints). The following results can be reported: Cronbach  $\alpha$  for model A of 0.58 (depicting a desirable low inter-correlation among indicators, one that is lower than for 15 variables in model B (0.63)); a Hosmer-Lemeshow  $\chi^2(8) = 10.50$ ,  $p = .23$  for model A vs. Hosmer-Lemeshow  $\chi^2(8) = 10.05$ ,  $p = .26$  of model B (both models do not depict evidence of a lack of fit, yet as the deviance statistic  $D^*$  of 0.45 at a 5% type I error rate is below the chi-squared statistic of 9.488 at 4 degrees of freedom (the difference in number of regression parameters), we cannot reject the null hypothesis that the parsimonious model A is statistically equivalent to the comprehensive model B and thus superior); a mean variance inflation factor for model A of 1.21 vs. 22.63 for model B; the residual analysis showed that for model B two households would have changed the covariate labour age at the 5% significance level (for which they would have needed to be excluded from the model), whereas model A does not require any such exclusion as individual households did not impact on the 5% significance levels of covariates; both models showed no specification error (both linktests were statistically non-significant), indicating no significant covariates were omitted (and thus the *parsimony* rule applies); the area under the ROC curve for model A is 0.76 vs. 0.75 for model B (thus both have “fair” test results, and the *parsimony* rule applies). Finally, a Wald Statistic of parameter constraints shows that the coefficients in model A are not simultaneously equal to zero (are insignificant jointly), meaning that including all eleven variables in the model creates a statistically significant improvement in the fit of the model (Wald  $\chi^2(11) = 47.08$ ,  $p = .0001$ ).

predictors in the models (Shively, 2011: 62). Detailed justifications of indicators that were selected are presented in SI3, complementary with summary statistics about each predictor and a Spearman rank correlation coefficient ( $r_s$ ) between all predictors and all nine variables comprising AMP (see Table 1 in SI3)).

We use the predictors in two robust multiple logistic regression (MLR) models to explain the size of the effect of being AMP. The objective of this stepwise regression is to analyse 1) the multiplicative effect of charcoal and alternative predictors in a comprehensive model (a), *ceteris paribus*; and 2) the *joint impact* of interaction terms on predictors found to be significant in a parsimonious second model (b) (following the application of a deviance statistic<sup>10</sup>  $D^*$  at a 5% type I error rate that compared the model fit between the comprehensive model (a) and parsimonious model (b)). Findings are presented at the aggregate (entire sample size), and disaggregate (village) level in the parsimonious MLR model b. This allowed interpretation of the data with regard to a possible Yule-Simpson effect that potentially occurs due to different sample sizes<sup>11</sup> when the data is disaggregated (see David & Edwards, 2001). Results of a robustness test on MLR model (a) are provided (in the endnotes (xvii)), where two alternative specifications of the binary variable  $Y_i$  are used as the endogenous variable). An explanation of the relationship between charcoal income and AMP is then offered.

If not otherwise stated, we report the number of observations  $n$ , the pseudo  $R^2$  for the comprehensive models (a) and the parsimonious model (b) at the aggregate and disaggregate level, the regression parameter estimates, their standard errors and corresponding  $z$  statistics, their significance level, and the odds ratios. Both models were tested with a specification link test for single-equation models (where a non-significant *linktest* indicates no-specification error in the model). Standard errors were adjusted through robust estimations. Probability weights were calculated and applied throughout. Data for the analysis were retrieved from a relational database management system using Structured Query Language (Chamberlin & Boyce, 1974). Unless specified otherwise, all analyses were conducted using STATA (StataCorp 2013) and Microsoft excel (2013).

### 3. Results

#### 3.1. Classification and analysis of charcoal producers

Charcoal production is the primary means of generating cash income by households at our study site (183, 70% of the sample ( $n = 261$ )). Wild fruit collection and other forms of direct forest income from unprocessed forest products, such as from selling or bartering poles, were also utilised by households as cash generators, but in most cases were rather used for subsistence (78). Only 17 households were found to have had a cash income from direct forest income, in the form of pole sales. These activities supplemented other environmental and non-environmental activities, foremost smallholder subsistence agriculture (217, of which only 12 households were engaged in cash cropping), animal husbandry (156), low skilled wage labour (25) or business income (25). The average number of income streams was found to be  $2.9 \pm 0.1$ .

We find no statistically significant variation in the relative number of households involved in charcoal production across the charcoal producing villages, neither in the production mean. However, we do find that charcoal production is positively skewed (3.26). Table 3 shows

<sup>10</sup> Expressed as  $D^*(y;\hat{\mu}) = 2l(y;\hat{\mu}_{(a)}) - 2l(y;\hat{\mu}_{(b)})$  where the scaled deviance statistic is twice the difference between the maximum log likelihood of the parsimonious model (b) and the comprehensive model (a). A Hosmer-Lemeshow  $\chi^2_{df}$  with df as. degrees of freedom is applied to test the null hypothesis  $H_0$  that model (a) is as good a fit as model (b) (Alkire et al., 2015: 306ff).

<sup>11</sup> Due to small sample sizes  $n$  at the village level we also tested MLR model b for a 1% type I error rate that yielded no impact on results (not reported).

**Table 3**

Analysis of charcoal production across villages and their main characteristic. Mabalane District, Gaza province.

	Matl A	San B	Tins C	Mav D	Mabu E	Hoch F	Match G	Total
Households (HH) producing charcoal (% of n)	29 (83)	23 (92)	46 (90)	22 (61)	21 (50)	42 (88)	0 (0)	183 (70)
Production total (Sacks <sup>-1</sup> )	4355	1979	6837	n.o.	3547	3982	0	20700
Production mean	150 ± 20	90 ± 12	149 ± 24	n.o.	169 ± 36	95 ± 20	0	131 ± 11
Production median	120	83.5	115	n.o.	130	62.5	0	100
No. of HH production total ≤ mean production (% of n)	20 (69)	12 (52)	27 (59)	n.o.	13 (62)	27 (64)	0 (0)	108 (67)
No. of HH production total ≤ median production (% of n)	17 (59)	11 (48)	23 (50)	n.o.	11 (52)	21 (50)	0 (0)	87 (48)
Share (%) of total sack production of HHs producing above the mean (Production sacks <sup>-1</sup> )	56 (2440)	67 (1331)	73 (4965)	n.o.	77 (2715)	75 (2976)	0 (0)	66 (13694)

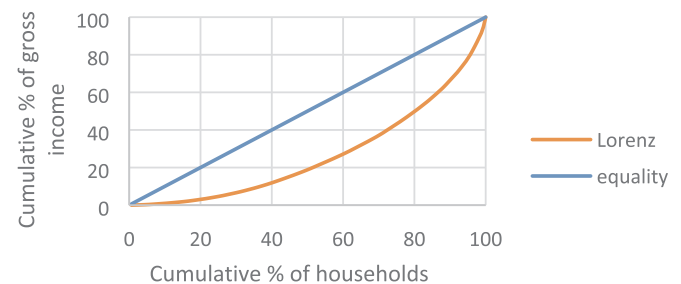
All data refer to year 2013–2014. n.o.: no observation. Mean value ± standard error. Percentages adjusted for n.o. n: sample size. Village names are abbreviated. Matl A = Matlantimbuti; San B = Sangue; Tins C = Tindzwaene; Mav D = Mavumbuque; Mabu E = Mabuapense; Hoch F = Hochane; Match G = Matchele.

that on aggregate two-thirds of charcoal producing households produced fewer than the mean number of charcoal sacks in the reference year (and half of the sample produced below the median (160)), whereas the 33% of households who produced on average above the mean were able, in turn, to produce 66% of the total production that year.

Charcoal producers can then best be classified by income quintile derived from their production quantity.<sup>12</sup> We find that average income of the first quintile was 5618 ± 457 MZN, whereas of the fifth it was 92164 ± 9102 MZN.<sup>13</sup> Consequently, as can be seen in the Lorenz curve presented in Chart 1, we find that the bottom quintile generates only 3.1% of the total gross income share, whereas the best-off quintile generates 50%. Thus, 80% of charcoal producing households generate cumulatively only half of the cumulative gross income. The resulting Gini of 0.479 portrays a higher level of inequality if compared to the official Gini coefficient based on per capita consumption measures (Rural Gini of 0.377 (2008/09), urban Gini of 0.506 (2008/09), national Gini 0.458 (2008/09) (Arndt, Jones, & Salvucci, 2015: 460).

With regard to monetary poverty, we find that gross income from charcoal making is not enough, *ceteris paribus*, to lift members of the average charcoal producing household out of extreme monetary poverty (or even for household members of the 4th income quintile). The average income of the charcoal producing households is 36415 ± 2995 MZN. Calculated on a daily basis the charcoal producing household generates 99.8 ± 8.2 MZN/day. With an average household size of 6.03 ± 0.25 in the study area, this converts to 16.6 ± 1.3 MZN per person/day (or 1.02 ± 0.08 US\$/day (PPP)).<sup>14</sup> This is below the then valid extreme poverty line of 1.25 US\$/day (PPP). In other words, even with a positively skewed income distribution remains the average charcoal producer in extreme poverty (the 4th income quintile from charcoal making (41312 ± 1001 MZN) also remains in extreme poverty (1.15 ± 0.02 US\$/day(PPP))). In other words, the charcoal income of approx. 80% of charcoal producing households is not sufficient to lift its household members out of extreme monetary poverty, *ceteris paribus*. Only the best-off income quintile can be considered to be out of extreme monetary poverty. Calculated on a daily basis, households of the best-off quintile generate 252.5 ± 24.9 MZN/day. This converts to 2.58 ± 0.26 US\$/day (PPP).

A corresponding question we subsequently explore is whether the best-off quintile in particular is also out of AMP, and if so, whether this



**Chart 1.** Lorenz curve of income distribution from local charcoal production (Gini coefficient: 0.479). Mabalane district, Gaza province.

effect can be attributed to charcoal production. To answer these questions, we first map AMP in the study area, and then explore the marginal effect of charcoal income on AMP.

### 3.2. Acute multidimensional poverty

With the chosen identification function  $\rho$  as described in Table 2 we find that 167 households in our sample are in AMP. This translates into a headcount ratio of  $H = 63.3\%$  (a similar headcount to the one calculated for the Gaza province in the Multidimensional Poverty Index (60.1%) and the government's official  $H$  (65.2%), see Table 2 in SI2 for further information). On average, the AMP are deprived in the weighted sum of 67.7% of indicators (A), thus the breadth-adjusted headcount ratio is calculated as  $M_0 = 0.429$  (see Chart 2). Decomposed by villages, we find the greatest headcount ratio in Sangue, followed by Matchele, whereas the lowest headcount ratios are in Mabuapense and Mavumbuque. With the lowest average deprivation vector  $A$  presented in Mabuapense, we find this village to be the best-off according to the adjusted headcount ratio ( $M_0 = 0.238$ ), whereas the poorest village is Sangue ( $M_0 = 0.541$ ), despite having an “average” average deprivation vector of  $A = 68\%$ . Given a basic dominance analysis we find that results are robust to changes in  $w_j$ , meaning that Mabuapense (the least poor village by  $H$ ) statistically dominates Sangue (the poorest village by  $H$ ) if given an equal weighing system across indicators (see Chart 3).

Decomposed by dimension, we find the greatest relative contributor to  $M_0$  on aggregate to be human capital (39%), followed by social (35%) and economic capital (25%).<sup>15</sup> Again, findings are robust to an equal weighting scale (see Chart 4). As can be seen in Chart 5, the greatest individual contributor to  $M_0$  on aggregate is “food (in)security” (22%), whereas the least contributor is “under five mortality” (1%). The greatest contributors to  $M_0$  under an equal weighting scheme are

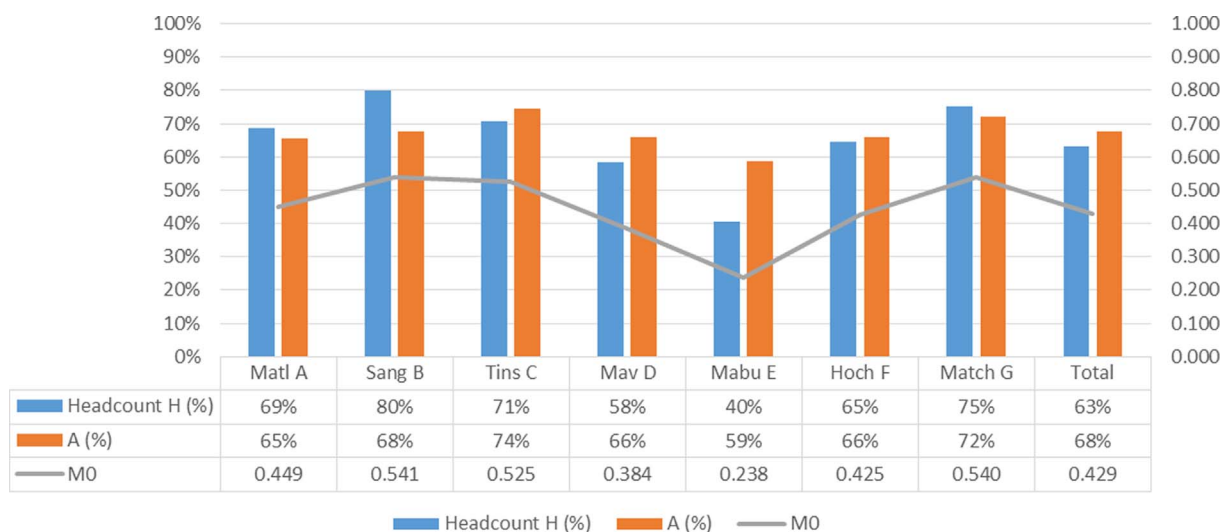
<sup>12</sup> Estimated gross income from charcoal making is calculated as quantity of production multiplied by estimated average price per unit (250 MZN per charcoal sack in Hochane, Mabuapense and Mavumbuque, 300 MZN in Matlantimbuti, Tindzwaene and Sangue).

<sup>13</sup> Exchange rate of 1 USD = 31.35 MZN for 2014 (LCU per US\$, period average; World Bank, 2016a).

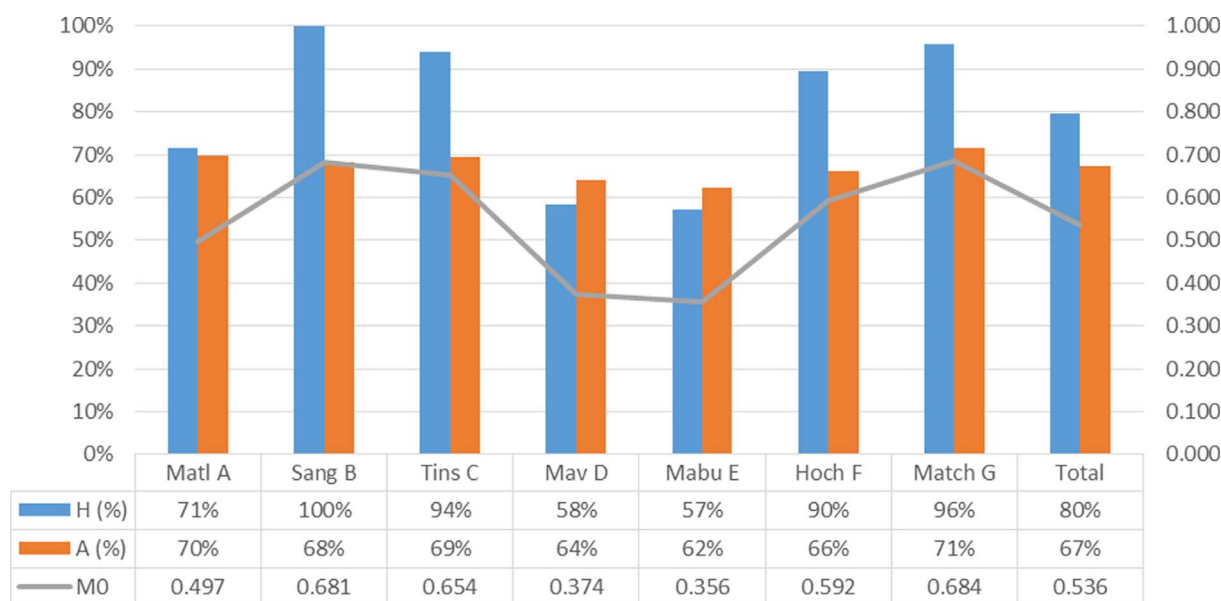
<sup>14</sup> Using the appropriate 2014 PPP conversion factor of 1 US\$ = 16.2 MZN (private consumption (LCU per international US\$); World Bank, 2016b).

<sup>15</sup> This is calculated by multiplying the headcount ratio  $H$  with the average deprivation share across the poor in indicator  $j$  ( $A_j$ ) (Alkire & Foster, 2009: 83).

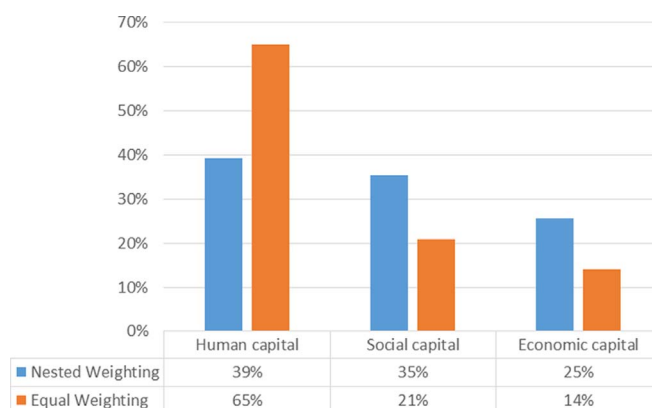




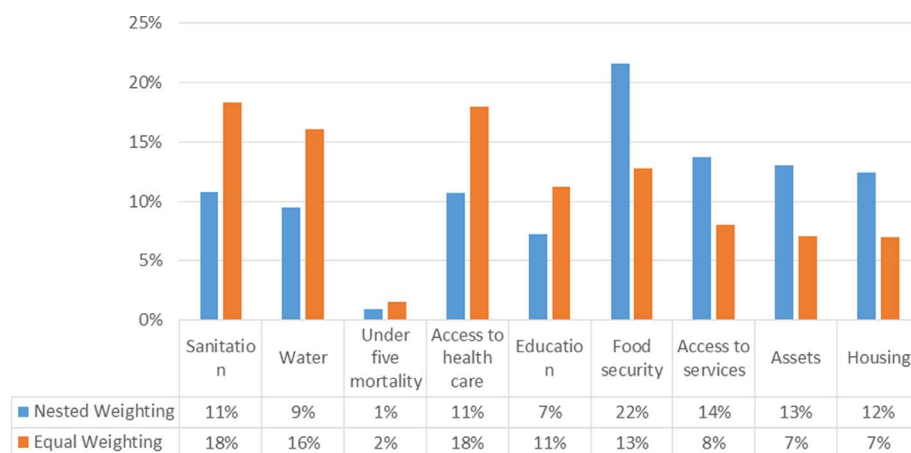
**Chart 2.** Headcount ratio H, average intensity of poverty A and breadth-adjusted headcount ratio  $M_0$  shown at aggregate and village level for nested weights at the study site in Mabalane district.



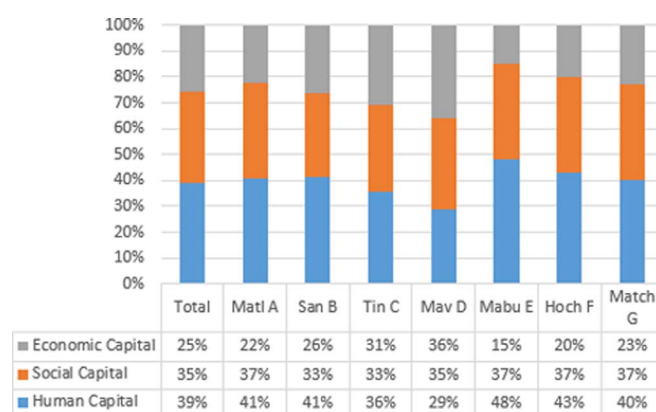
**Chart 3.** Headcount ratio H, average intensity of poverty A and breadth-adjusted headcount ratio  $M_0$  at aggregate and village level for equal weights at the study site in Mabalane district.



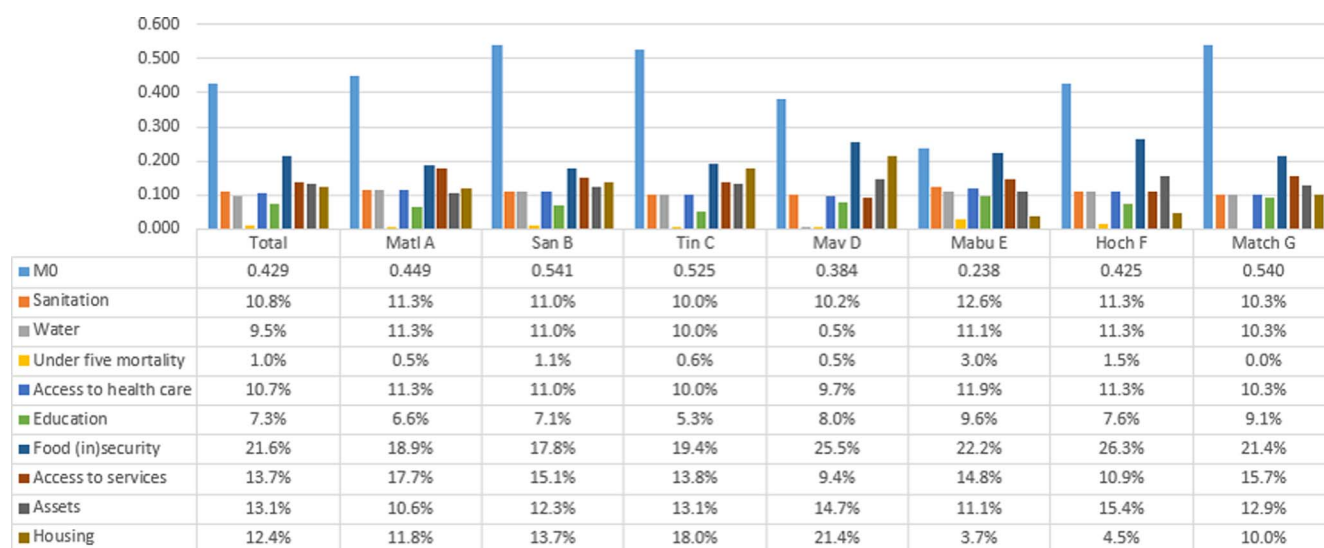
**Chart 4.** Dimensional contribution to breadth-adjusted headcount ratio  $M_0$  for nested and equal weights at the study site in Mabalane district.



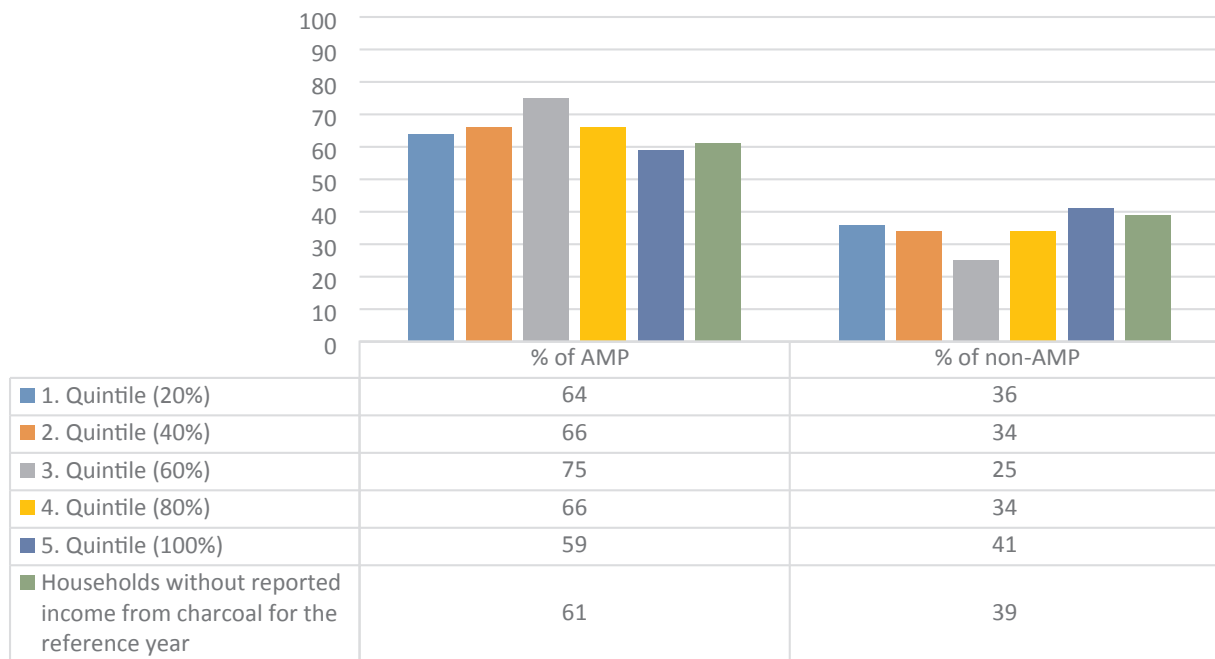
**Chart 5.** Contribution of each indicator to breadth-adjusted headcount ratio  $M_0$  for nested and equal weights, Mababane district.



**Chart 6.** Dimensional contribution to breadth-adjusted headcount ratio  $M_0$  decomposed by village for nested weights at the study site in Mababane district.



**Chart 7.** Contribution of each indicator to breadth-adjusted headcount ratio  $M_0$  decomposed by village for nested weights at the study site in Mababane district.



**Chart 8.** Percentage of households identified as acute multidimensional poor ( $Y_i = 1$ ) or otherwise ( $Y_i = 0$ ) placed in their respective income quintile from charcoal production at the study site in Mabalane district.

**Table 4**

Multiple Logistic Regression (MLR) Model a.  $n = 204$ . Pseudo  $R^2 = 0.169$ . Linktest: n.s. Reported are the regression parameter estimates, their standard errors and corresponding  $z$  statistics, as well as the odds ratios. Mabalane district.

Variable	Parameter Estimate		Robust Std. Err.	$z$	Significance Level	Odds ratio
1. Gross income from charcoal	3.69	4.42		0.84	n.s.	1.00
2. Cropland area size (ha)	−0.21	0.09		−2.28	*	0.81
3. Gross value of livestock	−2.96	1.34		−0.22	n.s.	0.99
4. Number of income streams (diversification)	0.35	0.16		0.21	n.s.	1.04
5. Business owned	−0.41	0.71		−0.57	n.s.	0.67
6. Wage income	0.00	0.00		1.24	n.s.	1.00
7. Female household head	0.52	0.49		1.04	n.s.	1.67
8. Household members in labour age	−0.29	0.1		−2.91	**	0.75
9. Years of residency	0.00	0.02		0.21	n.s.	1.00
10. Subjective perception of fortune	0.00	0.28		0.00	n.s.	1.00
11. Idiosyncratic shock experienced	1.34	0.35		3.88	***	3.90

\*Denotes significance at  $P < .05$ ; \*\*Denotes significance at  $P < .01$ ; \*\*\*Denotes significance at  $P < .001$ ; n.s. denotes non-significance.

equally “sanitation” and “access to equitable health care” (18%), whereas the least contributor remains “under-five mortality” (2%). In Mabuapense, economic capital contributes only 15% to  $M_0$ , which is below the dimensions’ relative contribution of 25% on aggregate (see Chart 6). This does not seem to translate to greater food security however, as Mabuapense has with 22.2% an above the average relative contribution of food (in)security to  $M_0$ , whereas Sangue has with 17.8% the least relative contribution of all villages to  $M_0$  (see Chart 7).

Further robustness and statistical inference tests are listed in SI2. There we find that  $\rho_k, H$  and  $\rho_k, M_0$  is unambiguously lower (or equal) for all village clusters for  $k \in [1, 5]$ . We therefore conclude that  $H$  and  $M_0$  display robust and confident values of AMP in the study area given the chosen identification function.

### 3.3. Determining the marginal effect of charcoal production on AMP

Chart 8 places the percentage of households identified as AMP ( $Y_i = 1$ ) next to their calculated income quintile from charcoal making. While it is not surprising to find the biggest share of non-AMP households being in the 5th quintile from charcoal production (41%), we find that 59% of the best-off quintile *are* considered to be in AMP. We also find that 39% of households without reported charcoal income are considered non-AMP (which combines data from non-charcoal-producing village Matchele (zero charcoal income) and missing data from charcoal producing village Mavumbuque).

**Table 5**

Multiple Logistic Regression (MLR) Model b. Linktest: n.s. Data reported at aggregate and disaggregate level. Reported are the regression parameter estimates, their standard errors and corresponding z statistics, as well as the odds ratios. Mabalane district.

Level	Variable	n	Parameter Estimate	Robust Std. Err.	z	Significance Level	Odds ratio
Aggregate <i>Pseudo R<sup>2</sup> = 0.142</i>	Cropland area size (ha)	259	−0.20	0.81	−2.52	**	0.82
	Interaction: ha (gender)	259	−0.90	0.24	−0.37	n.s.	0.91
	Interaction: ha (diversification)	259	−0.05	0.02	−2.26	**	0.95
	Interaction: ha (charcoal income quintiles)	161	−0.72	0.03	−2.51	**	0.93
	Interaction: ha (labour age)	259	−0.90	0.02	−3.58	***	0.91
	Household members in labour age	259	−0.32	0.87	−3.61	***	0.73
	Interaction: labour age (gender)	259	−0.21	0.16	−1.30	n.s.	0.81
	Interaction: labour age (charcoal income quintiles)	161	−0.06	0.03	−2.38	**	0.94
	Interaction: labour age (diversification)	259	−0.09	0.02	−3.58	***	0.91
	Idiosyncratic shock	259	1.16	0.29	4.01	***	3.2
	Interaction: shock (gender)	259	3.29	0.95	3.45	**	26.8
	Interaction: shock (diversification)	259	0.36	0.10	3.74	***	1.43
	Interaction: shock (charcoal income quintiles)	161	0.52	0.12	4.16	***	1.68
	Interaction: shock (labour age)	259	0.18	0.09	1.91	n.s.	1.19
	Interaction: shock (gender and labour age)	259	0.84	0.77	1.10	n.s.	2.33
Matl A <i>Pseudo R<sup>2</sup> = 0.401</i>	Cropland area size (ha)	34	−0.49	0.18	−2.72	**	0.61
	Interaction: ha (gender)	28	0	–	–	–	1
	Interaction: ha (diversification)	34	−0.11	0.06	−2.01	*	0.89
	Interaction: ha (charcoal income quintiles)	29	−0.16	0.07	−2.23	*	0.85
	Interaction: ha (labour age)	34	−0.17	0.06	−2.93	**	0.84
	Household members in labour age	34	−0.81	0.26	−3.17	**	0.44
	Interaction: labour age (gender)	28	0	–	–	–	1
	Interaction: labour age (charcoal income quintiles)	29	−0.17	0.10	−1.72	n.s.	0.84
	Interaction: labour age (diversification)	34	−0.36	0.11	−3.38	**	0.70
	Idiosyncratic shock	34	2.17	1.12	1.93	n.s.	8.75
	Interaction: shock (gender)	28	0	–	–	–	1
	Interaction: shock (diversification)	34	1.18	0.47	2.54	**	3.3
	Interaction: shock (charcoal income quintiles)	29	0.50	0.36	1.38	n.s.	1.65
	Interaction: shock (labour age)	34	−0.05	0.32	−0.17	n.s.	0.95
	Interaction: shock (gender and labour age)	30	0	–	–	–	1
San B <i>Pseudo R<sup>2</sup> = 0.148</i>	Cropland area size (ha)	25	−0.41	0.26	−1.57	n.s.	0.66
	Interaction: ha (gender)	24	−14.57	2.11	−6.89	***	4.7
	Interaction: ha (diversification)	25	−0.20	0.08	−2.40	*	0.82
	Interaction: ha (charcoal income quintiles)	23	−0.18	0.10	−1.88	n.s.	0.83
	Interaction: ha (labour age)	25	−0.06	0.05	−1.12	n.s.	0.94
	Household members in labour age	25	0.13	0.32	0.90	n.s.	1.14
	Interaction: labour age (gender)	24	6.90	0.58	11.98	***	993.2
	Interaction: labour age (charcoal income quintiles)	23	0.05	0.10	0.54	n.s.	1.05
	Interaction: labour age (diversification)	25	0.12	0.09	1.29	n.s.	1.13
	Idiosyncratic shock	25	1.03	1.14	0.90	n.s.	2.79
	Interaction: shock (gender)	24	0	–	–	–	1
	Interaction: shock (diversification)	25	0.03	0.32	0.08	n.s.	1.03
	Interaction: shock (charcoal income quintiles)	23	0.18	0.36	0.49	n.s.	1.20
	Interaction: shock (labour age)	25	0.18	0.28	0.65	n.s.	1.2
	Interaction: shock (gender and labour age)	24	0	–	–	–	1
Tin C <i>Pseudo R<sup>2</sup> = 0.123</i>	Cropland area size (ha)	51	−0.02	0.22	−0.10	n.s.	0.98
	Interaction: ha (gender)	45	2.53	1.4	1.8	n.s.	12.59
	Interaction: ha (diversification)	51	−0.02	0.07	−0.27	n.s.	0.98
	Interaction: ha (charcoal income quintiles)	46	−0.03	0.06	−0.52	n.s.	0.97
	Interaction: ha (labour age)	51	−0.01	0.05	−0.17	n.s.	0.99
	Household members in labour age	51	−0.58	0.22	−2.60	**	0.56
	Interaction: labour age (gender)	45	−0.99	0.89	−1.12	n.s.	0.37
	Interaction: labour age (charcoal income quintiles)	46	−0.06	0.05	−1.24	n.s.	0.94
	Interaction: labour age (diversification)	51	−0.14	0.05	−2.47	**	0.87
	Idiosyncratic shock	51	0.63	0.65	0.97	n.s.	1.88
	Interaction: shock (gender)	45	0	–	–	–	1
	Interaction: shock (diversification)	51	0.26	0.22	1.04	n.s.	1.25
	Interaction: shock (charcoal income quintiles)	46	0.36	0.20	1.80	n.s.	1.43
	Interaction: shock (labour age)	51	−0.20	0.22	−0.90	n.s.	0.82
	Interaction: shock (gender and labour age)	47	0	–	–	–	1

(continued on next page)



Table 5 (continued)

Level	Variable	n	Parameter Estimate	Robust Std. Err.	z	Significance Level	Odds ratio
Mav D <i>Pseudo R<sup>2</sup> = 0.07</i>	Cropland area size (ha)	36	−0.03	0.14	−0.23	n.s.	0.96
	Interaction: ha (gender)	32	0.33	1.05	0.31	n.s.	1.39
	Interaction: ha (diversification)	36	0.00	0.03	0.02	n.s.	1.00
	Interaction: ha (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: ha (labour age)	36	−0.07	0.03	−2.16	*	0.93
	Household members in labour age	36	−0.42	0.22	−1.85	n.s.	0.66
	Interaction: labour age (gender)	32	0.28	0.47	−0.59	n.s.	0.76
	Interaction: labour age (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: labour age (diversification)	36	−0.09	0.06	−1.57	n.s.	0.91
	Idiosyncratic shock	36	0.34	0.73	0.46	n.s.	1.41
	Interaction: shock (gender)	32	0	—	—	—	1
	Interaction: shock (diversification)	36	0.15	0.16	0.93	n.s.	1.16
	Interaction: shock (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: shock (labour age)	36	0.04	0.24	0.16	n.s.	1.04
	Interaction: shock (gender and labour age)	32	0	—	—	—	1
Mabu E <i>Pseudo R<sup>2</sup> = 0.181</i>	Cropland area size (ha)	42	−0.57	0.26	−2.22	*	0.57
	Interaction: ha (gender)	42	−0.34	0.59	−0.57	n.s.	0.71
	Interaction: ha (diversification)	42	−0.20	0.08	−2.37	*	0.83
	Interaction: ha (charcoal income quintiles)	21	−0.15	0.10	−1.42	n.s.	0.86
	Interaction: ha (labour age)	42	−0.19	0.08	−2.42	*	0.83
	Household members in labour age	42	−0.2	0.21	−0.93	n.s.	0.82
	Interaction: labour age (gender)	42	−0.59	0.48	−1.23	n.s.	0.58
	Interaction: labour age (charcoal income quintiles)	21	−0.05	0.05	−1.14	n.s.	0.95
	Interaction: labour age (diversification)	42	0.03	0.06	0.52	n.s.	1.03
	Idiosyncratic shock	42	1.34	0.73	1.83	n.s.	3.81
	Interaction: shock (gender)	42	2.32	1.39	1.67	n.s.	10.17
	Interaction: shock (diversification)	42	0.71	0.20	3.55	***	2.03
	Interaction: shock (charcoal income quintiles)	21	0.67	0.50	1.34	n.s.	1.96
	Interaction: shock (labour age)	42	0.52	0.25	2.05	*	1.68
	Interaction: shock (gender and labour age)	42	−0.18	0.40	−0.41	n.s.	0.85
Hoch F <i>Pseudo R<sup>2</sup> = 0.196</i>	Cropland area size (ha)	48	−0.37	0.21	−1.76	n.s.	0.69
	Interaction: ha (gender)	41	2.85	1.54	1.85	n.s.	17.24
	Interaction: ha (diversification)	48	−0.13	0.08	−1.58	n.s.	0.88
	Interaction: ha (charcoal income quintiles)	42	−0.06	0.07	−1.08	n.s.	0.93
	Interaction: ha (labour age)	48	−0.22	0.10	−2.11	*	0.80
	Household members in labour age	48	−0.53	0.23	−2.33	*	0.59
	Interaction: labour age (gender)	41	−0.6	0.78	−0.77	n.s.	0.55
	Interaction: labour age (charcoal income quintiles)	42	−0.04	0.09	−0.45	n.s.	0.96
	Interaction: labour age (diversification)	48	−0.18	0.07	−2.61	**	0.83
	Idiosyncratic shock	48	1.32	0.72	1.84	n.s.	3.76
	Interaction: shock (gender)	41	0	—	—	—	1
	Interaction: shock (diversification)	48	0.32	0.26	1.27	n.s.	1.39
	Interaction: shock (charcoal income quintiles)	42	0.70	0.29	2.44	**	2.02
	Interaction: shock (labour age)	48	0.27	0.24	1.11	n.s.	1.31
	Interaction: shock (gender and labour age)	41	0	—	—	—	1
Match G <i>Pseudo R<sup>2</sup> = 0.442</i>	Cropland area size (ha)	9	0.43	0.32	1.37	n.s.	1.54
	Interaction: ha (gender)	15	0	—	—	—	1
	Interaction: ha (diversification)	9	0.07	0.09	0.79	n.s.	1.07
	Interaction: ha (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: ha (labour age)	10	−0.07	0.09	−0.72	n.s.	0.93
	Household members in labour age	9	−3.37	2.59	−1.30	n.s.	0.03
	Interaction: labour age (gender)	15	0	—	—	—	1
	Interaction: labour age (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: labour age (diversification)	9	−0.62	0.40	−1.52	n.s.	0.54
	Idiosyncratic shock	9	0	—	—	—	1
	Interaction: shock (gender)	15	0	—	—	—	1
	Interaction: shock (diversification)	9	0	—	—	—	1
	Interaction: shock (charcoal income quintiles)	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
	Interaction: shock (labour age)	10	0	—	—	—	1
	Interaction: shock (gender and labour age)	16	0	—	—	—	1

\* Denotes significance at  $P < .05$ ; \*\* Denotes significance at  $P < .01$ ; \*\*\* Denotes significance at  $P < .001$ ; n.s. denotes non-significance; n.o. denotes no observations. Pseudo  $R^2$  for parsimonious model at aggregate and disaggregate level (without interaction terms). n: number of observations. Village names are abbreviated. Matl A = Matlantimbuti; San B = Sangue; Tins C = Tindzwaene; Mav D = Mavumbuque; Mabu E = Mabuapense; Hoch F = Hochane; Match G = Matchele.

Table 4 then presents findings of the comprehensive MLR model (a).<sup>16</sup> We find  $z$  statistics at the significant level for three covariates. For any given household, the log of the odds of being  $Y_i = 1$  decreases by 19%, *ceteris paribus*, with a one unit increase of cropland area size (ha), and by 25%, *ceteris paribus*, with a demographic change that puts more household members into labour age. On the other hand, having experienced an idiosyncratic shock increases the odds of being AMP by 290%, *ceteris paribus*.<sup>17</sup> Charcoal income failed at the 5% significant level at the aggregate level; it also failed when  $Y_i$  is regressed individually against charcoal income (without any other predictors in the model (not reported)), and when charcoal income is normalised, categorized into quintiles and logarithmically transformed to account for the observed skewness and heteroscedasticity (this accounts as well for the same data analysis at the disaggregate or village level (not reported)). Additionally, an ordered logistic regression of charcoal income quintiles using  $Y_i$  as predictor was found to be statistically non-significant as well ( $z = -0.41$ ,  $p = .68$ ).

Following the application of the deviance statistic we drop<sup>18</sup> the non-significant predictors from MLR model (a) and use two of them, female household head and diversification, as interaction terms<sup>19</sup>

<sup>16</sup> When  $Y_i$  is regressed individually against the 11 variables of MLR model (a), in addition to “cropland area size”, “labour age” and “idiosyncratic shock”, we find that the covariates “diversification”, “female household head” and “subjective perception of fortune” also displayed  $z$  statistics at the significant level at 5%. Hence the continuous analytical usage of some of the predictors as interaction terms in MLR model (b).

<sup>17</sup> We tested the robustness of the findings in MLR Model a by varying the identification function  $\rho$  (where  $Y_i$  takes the value of one if and only if  $c_i \geq 3$  and  $c_i \geq 5$ , and zero if otherwise (not reported)). Thus we test results for a range of  $k$  values which displayed the most robust ranking results across the villages (see Figs. 1 and 2 in SI2). At the aggregate level, “labour age” dropped as a significant predictor of AMP for  $c_i \geq 3$ , while “diversification” and the “presence of a female headed household” turned into additional significant predictors of AMP for  $c_i \geq 5$  (decreasing the log of the odds by 32%, and increasing them by a factor of 2.6). For both alterations, charcoal income remains a non-significant predictor at the aggregate level. This finding was repeated at the disaggregate level, however a minor Yule-Simpson effect was observable for  $c_i \geq 3$  (where charcoal income turns into a significant predictor of AMP for Mabuapense, however at a size that decreases the odds of merely 1%). Thus, we consider the results obtained in the MLR model a to be robust against reasonable alterations of the identification function  $\rho$ . Results of MLR Model a remain robust as well when analysed only for a subsample of charcoal producers that sold their charcoal by the time the data collection took place (and thus reported to have a gross income from charcoal > 0 MZN ( $n = 161$ , adjusted to missing income data from 22 charcoal producing households in Mavumbuke; *Pseudo*  $R^2 = 0.177$ )). Area size, labour age and idiosyncratic shock remain significant predictors of AMP, whereas charcoal income remains a non-significant predictor at the aggregate level (also when  $Y_i$  is regressed individually against charcoal income, and when charcoal income is categorized into quintiles and logarithmically transformed). However, in just analysing that subsample, we find regression results on AMP less robust to changes in the identification function when a variation of charcoal income is used as predictor variable. Namely when charcoal income quintiles are used as predictor variable we find a significant marginal effect on reducing the odds of being  $Y_i = 1$  for  $c_i \geq 3$ , by 37%, *ceteris paribus* (*Pseudo*  $R^2 = 0.251$ ). We find an additional 32 households becoming multidimensionally poor with  $c_i \geq 3$  ( $H_{c_i \geq 3} = 86\%$ ). This constitutes an increase of 30% (from  $H_{c_i \geq 4} = 67\%$ ). While we observe a moderate comparative reduction in the average intensity of deprivations  $A$  (from  $A_{c_i \geq 4} = 67\%$  to  $A_{c_i \geq 3} = 60\%$ ), the prevalence of poverty  $M_0$  for  $c_i \geq 3$  is with 0.516 greater than for  $c_i \geq 4$  ( $M_0 = 0.449$ ). Thus, we find that with a greater prevalence of poverty (driven by a move towards a *union approach* in the identification function  $\rho$ ), the role of charcoal making for its producers in predicting deductions in the log of the odds of being AMP increases. A one-way ANOVA between charcoal income quintiles over  $Y_i = c_i \geq 3 = 1$  reveals a significant difference across the subsample ( $F(4156) = 2.81$ ,  $p = .02$ ). A Tukey post hoc test revealed that  $Y_i = c_i \geq 3 = 1$  was statistically significantly lower in the 5th quintile compared to 1st ( $-0.25 \pm 0.9$ ,  $p = .029$ ). This translates to a significant low-to-moderate semi-elasticity of 0.68 of AMP when charcoal income data is logarithmically transformed.

<sup>18</sup> The deviance statistic  $D^*$  of 2.25 at a 5% type I error rate was identified between the comprehensive MLR model (a) (Hosmer-Lemeshow  $\chi^2(8) = 10.50$ ,  $p = .23$ ) and an alternative parsimonious MLR model (b), one that contained only the three significant predictors of AMP (Hosmer-Lemeshow  $\chi^2(8) = 8.25$ ,  $p = .40$ ). As the deviance statistic  $D^*$  is below the chi-squared statistic of 15.507 at 8 degrees of freedom we cannot reject the null hypothesis that the parsimonious model is statistically equivalent to the comprehensive model.

<sup>19</sup> While interaction terms were included in MLR model b, second-order terms were excluded as their inclusion would have not improved the model fit and the parsimonious rule applies (scaled deviance statistic  $D^*$  between MLR model b and potential MLR model b.2 of 1.55 at a 5% type I error rate is below the chi-squared statistic of 5.991 at 2 degrees of freedom).

instead in the more parsimonious MLR Model (b); as additional interaction terms we use charcoal income (this time as quintiles), and where applicable, household members in labour age.

Findings are presented in Table 5. Results are presented at the aggregate and disaggregate level. We find that a one unit (ha) increase in managed cropland area size significantly lowers the log of the odds of being AMP in best-off village Mabuapense (by 43%), in contrast to a non-significance in worst-off village Sangue. However, we also found that labour age drops as a significant predictor in Mabuapense. While it seems befitting that an idiosyncratic shock is a non-significant predictor of  $Y_i = 1$  in best-off village Mabuapense, the non-significance of an idiosyncratic shock in the poorest village Sangue seems counterintuitive.

When used as interaction terms we found diversification and charcoal income act as coping mechanisms that absorb the impact of an idiosyncratic shock. While still severe, in both cases the log of the odds of being  $Y_i = 1$  decreases by a factor of 2.2 and 1.9, to 43% and 68% respectively, *ceteris paribus*. When disaggregated however, the effect was only significant in the village Hochane when adjusted for charcoal income, but not in the best-off village Mabuapense. There, the interaction term diversification was statistically significant.

In addition we found that, on aggregate, area size and labour age drop as significant predictors of  $Y_i = 1$  given the gender of the household head as an interaction term (a finding that is only non-applicable at the village level for Sangue, which is indicative of a minor Yule-Simpson effect). Thus, we do not find any covariate, at the aggregate level, that could explain deductions at the 5% significance level in the log of the odds of being  $Y_i = 1$  for female headed households. On the contrary, we find that the odds ratio of being  $Y_i = 1$  after an idiosyncratic shock experienced by the household worsens when female-headed (increases of the odd ratio by a factor of 8.4). This is however softened if additionally explained by household composition. Even when female headed, an idiosyncratic shock turns into a statistically non-significant predictor of  $Y_i = 1$  given household members of labour age as an interaction term.

### 3.4. Explanation of the relationship between charcoal income and AMP

Charcoal income failed to explain the marginal effect of being non-AMP (see MLR Model a, Table 4); this finding is the same as well at the disaggregate level (not reported), thus even in best-off village Mabuapense (see Chart 2) – the village in which economic capital contributed severely less to the adjusted headcount ratio  $M_0$  in comparison to the other villages (15%, see Chart 6). Thus, even in the village with the least amount of households in AMP (40%), and where the AMP are economically better off in comparison to the AMP in the other villages, we find a lack of evidence that this is *due* to charcoal income. Furthermore, even for the best-off income quintile do we not find that their greater charcoal production translates to a statistically significant deduction in the likelihood of being AMP ( $z = -0.41$ ,  $p = .68$ ); particularly female headed households are at risk of being AMP, even if they produce charcoal (see MLR Model b). If charcoal income is applied as an interaction term in MLR model b however, it was found to be a statistically significant coping strategy that reduces the log of the odds of being in multidimensional poverty if the household experienced an idiosyncratic shock, such as a serious crop failure. If disaggregated however, this effect was not significant in best-off village Mabuapense. In other words, cash income from charcoal production is potentially helpful to prevent descending into multidimensional poverty by increasing the resistance to shocks, yet evidence is weak if the data are disaggregated. Overall, our findings show the importance of local charcoal production as a coping strategy, yet challenges the perception that charcoal income can eventually eliminate poverty if a multidimensional concept is used.

Two main reasons can explain the observation why charcoal income is not a significant predictor of AMP:

1. A Spearman rank correlation coefficient ( $r_s$ ) between all eleven predictors and the nine censored variables comprising the identification function  $\rho$  of AMP (see Table 1 of SI3, where variables of  $\rho$  are coded as 0 = deprived and 1 = non-deprived) revealed that gross income from charcoal

making is significantly and positively correlated with formal education (0.17) and assets owned (0.2). Yet, it is not significantly correlated with food security as well as the combined access to services, associations and credit variable. These are the two biggest contributing variables  $j$  to  $M_0$  at the aggregate level (with 22% and 14% respectively, see Chart 5).<sup>20</sup> Food insecure households borrow food or money as their main coping strategies, rather than producing more labour intensive charcoal (see summary statistics of sub point food security in SI1). This stands in contrast to the experience of an idiosyncratic shock, where we find that the most applied coping strategy to be the harvest of more forest products (see summary statistics of sub point idiosyncratic shocks experienced in SI3). This explains why charcoal significantly lowers the log of the odds of being AMP if it is used as an interaction term on the experience of an idiosyncratic shock in MLR model *b*. Also, the negative correlation of food security with an idiosyncratic shock ( $-0.52$ ), the second highest correlation overall, and female household head ( $-0.16$ ) helps to explain the significant role of these predictors in that model. The moderate correlation of charcoal income with assets can be interpreted as a positive spill over effect on acute multidimensional poverty (with assets being positively correlated with sanitation (0.14), water (0.14), education (0.26), food security (0.22), and housing (0.16)). However, as assets are also positively correlated with a number of other livelihood related predictors such as area size (0.26) or value of livestock (0.35), charcoal income is not solely responsible for that effect.

2. A Kruskal-Wallis H test revealed a statistically non-significant difference in gross charcoal income over  $Y_i$ <sup>21</sup>; charcoal income quintiles over  $Y_i$  were also found to not vary as established by a one-way ANOVA.<sup>22</sup> Consequently, a statistically significant variance in charcoal income over  $Y_i$  was not identified. The regressed  $z$  statistic of 0.84 in MLR model *a* is a reflection of this non-variance.<sup>23</sup> It displays a pattern of charcoal income distribution that could have been the result of a random distribution.

#### 4. Discussion

This paper focused on the scope and limitations of charcoal income to alleviate poverty in the multidimensional sense. Multidimensional poverty is understood as the inability of household members to meet minimum national and international standards and core *functionings* (see Alkire & Santos, 2010a, 2010b, 2014), while alleviations of multidimensional poverty encompasses both the prevention and eventual elimination of poverty (Sunderlin et al., 2005). Mozambique was chosen as a case study because it typifies the challenge of managing mopane woodlands for the benefit of the rural poor in southern Africa. Our findings show a high intensity (67.7%) and prevalence of AMP (0.429) in the study area, based on the Alkire-Foster method. Charcoal income is found to be positively correlated with valuable household assets, and charcoal production increases the resistance to the likelihood of impoverishment in certain circumstances (where resistance is understood as the capacity to absorb a sudden or chronic shock (Roussy, 2013: 5)). However, charcoal income was not found to be a statistically significant determinant of AMP, even for the most productive charcoal makers. 59% of the

identified non-monetary poor from charcoal making are identified as acute multidimensionally poor.

Interestingly, this confirms and challenges existing studies that found charcoal to be a potential route out of poverty<sup>24</sup> (see Ainembabazi et al., 2014; Fisher, 2004; Schure et al., 2014; Shackleton et al., 2007; Yemiru et al., 2010). Increased charcoal production certainly allows for the generation of more cash income; and indeed, the best-off charcoal income quintile produced enough charcoal to be considered out of extreme (monetary) poverty, *ceteris paribus* (this confirms findings in Ainembabazi et al. (2014)). However, in our study area, the average charcoal producer, and even the 4th income quintile, does not earn enough income to be lifted above the extreme monetary poverty line with charcoal income, *ceteris paribus*. Thus, even with a positively skewed income distribution does the production of charcoal not constitute a pathway out of monetary poverty for the average producer (which confirms findings of Schure et al. (2014: S85)). Additionally, we do not find charcoal income to be significantly correlated with livelihood diversification overall, or other very important livelihood streams, such as value of livestock, business income or wage labour income (see Table 1 in SI3).<sup>25</sup> This stands in contrast to studies that found charcoal to be a take-off activity to venture into diversified livelihood activities (see Zulu & Richardson, 2013), that, in some reported cases, led to poverty reductions (Schure et al., 2014).<sup>26</sup>

Most importantly for the analysis in this paper however, we conclude that increased charcoal income does not inevitably determine escapes from acute multidimensional poverty (even for the best-off charcoal income quintile). We rather find that charcoal production increases the resistance to the likelihood of multidimensional impoverishment in certain circumstances (e.g. when charcoal is applied as a

<sup>24</sup> We were unable to verify whether the best-off income quintile, whose charcoal income in 2013–14 was enough to lift them out of monetary poverty, were already non-monetary poor by the time the data collection took place. This is due to a lack of panel data, which this study has in common with most of the reviewed studies in this paper (i.e. Ainembabazi et al., 2014; Shackleton et al., 2007). Hence the subsequent usage of the *ceteris paribus* clause in the estimations of monetary poverty rates. Related to this, also unbeknownst to us is the potential impact that charcoal income and other determinants may have had in the past on the calculated AMP status of households. Both questions are subject to ongoing research.

<sup>25</sup> We find a positive correlation of charcoal income with household savings ( $r_s = 0.2$ ,  $p = .003$ ). Charcoal thus has welfare benefits as identified elsewhere in the literature (Schure et al., 2014; Shackleton & Shackleton, 2004a, 2004b). However, the correlation is moderate, as only 24 households reported to have cash savings (1950 ± 650 MZN (SE)). Savings are also positively skewed (6.9). Schure et al. identified that “most [household] savings are spent for coping with shocks, rather than in accumulating assets” (2014: S88). As we do not find a significant correlation between savings and shocks ( $r_s = -0.02$ ,  $p = .7$ ), yet between savings and household assets ( $r_s = 0.2$ ,  $p = .001$ ), we find this to be different in this study region. As we find that the most applied coping strategy to shocks is to harvest more forest products (see summary statistics of sub point idiosyncratic shocks experienced in SI3), we find our results to be closer to study findings that see the harvesting of forest products as a more important coping strategy to shocks than resorting to savings (see Godoy, Jacobson, & Wilkie, 1998).

<sup>26</sup> Only if part of a strategy to diversify the livelihood portfolio which eventually leads to a business creation is charcoal making useful in the potential alleviation of AMP. We used confirmatory principal component factoring (Costello & Osborne, 2005) to collapse the eleven covariates into latent variables (not reported). This was done to understand the effect of latent variables that connect the eleven covariates. PCF revealed four uncorrelated factors with an *eigenvalue* equal to or greater than one, which were retained following the Kaiser criterion (see Costello & Osborne, 2005). Together, they explain 55.8% of the total variance in the observed variables. Each factor is comprised of observed variables that hold the strongest factor loadings (or standardised regression coefficients). The strongest correlation of factor 1 is with years of “years of residency” and “household members in labour age”, factor 2 with “business ownership” and “diversification”, factor 3 with “idiosyncratic shock” and “subjective perceptions of fortune”, and factor 4 with “wage income” and “cropland area size”. Charcoal income was found to have a low regression coefficient that prevents the variable being identified in the factor loadings with an *eigenvalue* greater than one. The identified factors were then used in another MLR model ( $n = 204$ ; *Pseudo R*<sup>2</sup> = 0.101). For any given household, the log of the odds of being AMP decreases, *ceteris paribus*, with an increase in factor 1 (by 40%) and factor 2 (by 35%), yet increases by 60% with an increase in factor 3. Factor 4 produced a  $z$  statistic that failed the 5% significance level. We conclude that if business income is aspired to, income diversification is more important than increased charcoal production (and indeed, as can be seen in see Table 1 in SI3, diversification and business ownership is significantly and positively correlated (0.29)).

<sup>20</sup> In contrast, the two predictors found to show deductions in the likelihood of being  $Y_i = 1$  at the aggregate level, namely cropland area size and labour age, were found to have significant correlations with indicators across three and two dimensions of AMP respectively (cropland area size with sanitation (0.18), water (0.16), access to services, associations and credit variable (0.36) and assets (0.26), and labour age with sanitation (0.18), education (0.39), assets (0.45) and housing (0.26)).

<sup>21</sup>  $\chi^2(1) = 0.009$   $p = .92$ . A Shapiro-Wilk  $W$  test for normality revealed a non-normal distribution of charcoal income ( $W = 0.737$ ,  $p = .00001$ ).

<sup>22</sup>  $F(4,156) = 0.46$ ,  $p = .77$ . A Shapiro-Wilk  $W$  test for normality revealed a normal distribution of charcoal income quintiles ( $W = 0.99$ ,  $p = .68$ ).

<sup>23</sup> This also helps to explain why the gross value of livestock was not a significant covariate in the MLR model *a* ( $z$  statistic of  $-0.22$ ). While livestock is positively correlated with sanitation (0.18), under five mortality ( $-0.14$ ), food security (0.19), access to services (0.25), assets (0.35) and housing (0.32), thus with six out of nine variables across all three dimensions of AMP, a one-way ANOVA was unable to establish a statistically significant difference between quintiles over  $Y_i$  ( $F(4,143) = 2.14$ ,  $p = .07$ ).

coping strategy to respond to idiosyncratic shocks such as livestock loss or crop failures). This locates our findings closer to literature that identified the important role of charcoal cash income on poverty prevention (FEWSNET, 2011; Kalaba et al., 2013; Levy & Kaufman, 2014 or Kambewa et al., 2007). However, while charcoal income can act as a *coping strategy* that increases the resistance from multidimensional impoverishment, evidence is insufficient to label the production of charcoal a *safety net* from multidimensional impoverishment. Too many charcoal producing households have been found to be in AMP in order to justifiably make that claim (and the log of the odds of being AMP remains high when households are struck by an idiosyncratic shock (68%), even if charcoal can be produced to cope with the shock).

Some studies have found small-scale producers to be trapped in “perpetual poverty” given their reliance on charcoal while lacking alternative off and on-farm income sources (Ndegwa et al., 2016: 173). In our study, and its focus on AMP, such a finding may be premature. 36% of the lowest income quintile were found to be non-AMP, while being in monetary poverty. However, given that charcoal production is the main cash generator in our study site, we find the lack of correlation of charcoal income with other income streams in light of the (obviously corresponding) non-significant semi-elasticity of AMP to charcoal income, worrisome. It requires future analysis preferably with panel data to better understand their varying poverty statuses over time, to make an informed assessment if these households are in a poverty trap.

Comparisons of findings to other charcoal studies are done with the caveat that results are strongly determined by contextual factors, such as geographical location and the entrenchment of local producers in poverty (that is the depth, severity and dynamics of poverty). Studies are also characterised by a strong theoretical and methodological heterogeneity (Angelsen et al., 2014; Vedeld, Angelsen, Sjaastad, & Berg, 2004). Given the embeddedness of most reviewed studies in ecological, welfare and livelihood economics, as highlighted in the introduction, we find that studies interpret the value of charcoal production to poverty reduction in the way producers invest revenues in other household activities.<sup>27</sup> The focus of this study was to purposefully study the contribution of charcoal cash income to AMP in order to complement these existing studies on the contribution of charcoal to poverty. This necessitates situating the findings also in the context of a multidimensional poverty debate, which is still nascent and most strongly embedded in development and social economics.

Our findings suggest overlaps between the monetary poor and the multidimensional poor in our study site. However, we also detect a great number of non-monetary poor that are in AMP, and *vice versa*. This confirms findings of Wang et al. (2016) and other authors (see

Alkire et al., 2015; Ataguba et al., 2013; Castro et al., 2012; Ruggeri-Laderchi et al., 2003) that identified that income and multidimensional poverty do not necessarily overlap. As we find no statistically significant reduction in the log of the odds of being AMP with increases in charcoal income, we divert from study findings that identified modest reductions in multidimensional poverty with an additional individual income (Suppa, 2016). The non-significant semi-elasticity of AMP to charcoal income found in this study site<sup>28</sup> needs to be seen in light of emerging research findings that thus far suggest that the elasticity of multidimensional poverty to economic growth is low (Mahoozi, 2016) or respectively lower in comparison to the elasticity of income poverty (Santos et al., 2016). In some cases, studies were unable to identify a clear “association of multidimensional measures with GDP p.c. or the growth thereof” (Suppa, 2016: 24). Santos et al. interpret the low elasticity of acute multidimensional poverty to economic growth as proof that “[economic] growth does not seem to be particularly pro-poor when poverty is measured from a multidimensional perspective” (2016: 28). Their results “highlight the need for countries to grow in order to reduce poverty, but they simultaneously suggest the limited power of economic growth *per se* to achieve grand reductions in poverty” (2016: x).

These are arguments that can be reiterated here. While we find charcoal income unable to determine eliminations of AMP in this site, charcoal income still leads to improvements in the human and economic capital of the poor. The finding that the poorest income quintile only generates 3.1% of all charcoal income yet has 64% of households in AMP means that their lack of inclusion in the charcoal value chain deprives that group in particular of the opportunity to use charcoal income as a means to achieve such valuable accumulations in assets or education. This being said, on average the acute multidimensional poor in our study site were deprived in 67.7% of indicators (the average intensity *A*). This reflects the high intensity of AMP in Mabalane district. Suppa argued in his analysis of multidimensional poverty in Germany that deeply entrenched deprivations are “difficult to fix—even with ample resources—and thus they are likely to be only loosely related to income” (2016: 20). Again, this argument can be reiterated for this case study, as proven by the 59% of households of the best-off income quintile that were non-monetary yet multidimensional poor.

Hence, overall are our findings best placed in line of poverty literature that identifies that “growth is not enough” in order to achieve sustained escapes from poverty (see Krishna, Kapila, Porwal, & Singh, 2007). For instance, while greater charcoal income can bring welfare benefits to the people in Mabalane district, access to equitable health care cannot be achieved by greater household income alone, but by improving the physical availability, social acceptability and financial affordability of health care in the region (Evans, Hsu, & Boerma, 2013; McManus, 2014; Saksena, Hsu, & Evans, 2014; World Health Organization, 2014). Households with less members in labour age 15–64 – who are more likely to be in multidimensional poverty – face physical challenges in making charcoal. They are better served, as could be argued, by improving the social protection and pension scheme,

<sup>27</sup> Studies that use a monetary conceptualisation of poverty often focus on assessments of the depth and severity of poverty because income is a cardinal variable. Following Angelsen and Wunder (2003), this potentially means that the contribution of charcoal towards poverty alleviation is achieved when, for instance, producers move from a severe poverty status closer to the poverty line. In other words, while households might not leave poverty through charcoal production, charcoal income can still alleviate poverty if producers move closer to the poverty line (poverty is reduced). Multidimensional poverty assessments assess the breadth of poverty and often rely on ordinal data. Many *functionings* (achievements) are linked to human rights and are thus best captured with ordinal data. The often necessary dichotomisation of data is an acknowledged challenge in the literature on multidimensional poverty (Alkire & Foster, 2007). Further cut-off lines need to be identified to additionally assess the depth and severity of poverty if ordinal data are the best available data to identify the poor (as was the case for this study). As this was beyond the scope of analysis for this paper, we call for future research to account for the depth of multidimensional poverty by exploring the new AF method for ultra-deprivations used to obtain the depth of acute poverty (Alkire & Seth, 2016). Also, this study did not adopt the “vulnerable to poverty” and in “severe poverty” categories as lately put forward by the MPI (Alkire et al., 2016: 7–8; Oxford Poverty, 2015), as this was beyond the scope of analysis as well; yet the average intensity of poverty (*A*) in Mabalane district of 67.7% would be severe enough, as could be argued, to label the average multidimensional poor person in the study site as severe multidimensional poverty. But we call for further research into this observation. Overall, data availability was certainly a factor in the choice to focus this paper on the contribution of charcoal to poverty elimination, rather than poverty reduction.

<sup>28</sup> When charcoal income data is logarithmically transformed we detect a significant low-to-moderate semi-elasticity of 0.54 of the participatory wealth rankings – the relative poverty measure – to charcoal income. A propensity-score matching (PSM) experiment on the potential average treatment effect of “wealth-perceived” poverty – where households in the poorest and poor wealth ranking categories are categorized as being in relative poverty and the better-off and best-off as being out of relative poverty – on the actual charcoal income from the producers, using labour age as the independent treatment variable, revealed that on aggregate, being in “wealth-based” relative poverty causes a statistically significant reduction of charcoal income of  $-14792 \pm 5045$  MZN (SE) ( $n = 206$ ;  $z = -2.93$ ,  $p = .003$ ). This observation is worth exploring further. Future research suggestions also comprise an assessment and further exploration of the significant predictor “cropland area size” and its possible trade-offs with forest conservation and thus sustainable development. A PSM experiment on the potential average treatment effect of AMP on cropland area size, using again labour age as independent treatment variable, revealed that on aggregate, being in AMP ( $Y_i = 1$ ) causes a reduced area size of  $-0.66 \pm 0.28$  ha (SE) ( $z = -2.37$ ,  $p = .002$ ).



which is inadequate in Mozambique (Francisco, Sugahara, & Fisker, 2013), rather than being encouraged to accelerate efforts to produce labour intensive charcoal.

Policy makers in Mozambique face a new set of challenges with acute multidimensional poverty. Poverty in the multidimensional space is characterised by its *breadth*, and hence complexity, both in measurement (Alkire et al., 2015), and in strategies to achieve its alleviation and elimination in a sustainable manner. Recent research by LeBlanc (2015) highlights that *ending poverty in all its forms* (SDG target 1) is linked to progress in ten other SDG goals, with the thickest link to target 10 (*reduce inequality within and among countries*). This necessitates a coherently designed integration of cross-sectoral policies (Janus & Holzapfel, 2016; LeBlanc, 2015) that ensures that market mechanisms and efficient public service delivery effectively mix (see Bourguignon & Chakravarty, 2003). In Mozambique, this necessitates, firstly, a stronger role of the Ministry of Coordination of Environmental Affairs and the Ministry of Planning and Development in the implementation of the government's five year plan, as well as the *Floresta em Pé* and *Estrela* programmes; and secondly, a more equitable and inclusive charcoal industry in this region. We observe a large unequal income distribution from charcoal production at the local level, and linked studies have highlighted that the majority of charcoal income in the study site was generated by non-residents (Baumert et al., 2016a: 137). Concentrated policy interventions are required that target the better integration of local producers into the charcoal industry. This could be achieved by introducing quotas to licences that ensures a minimum hiring of local producers (similar to controls introduced on foreign capital inflows, see Cornia, 2006: 14), by stabilizing charcoal prices paid to local producers at competitive levels (see Saget, 2006), and by adjusting the legal framework to make it easier for small-scale charcoal producers to participate in the trade (Baumert et al., 2016a: 137).

## 5. Conclusion

This paper analysed the instrumental value of charcoal income to the alleviation of acute multidimensional poverty in Mabalane district, southern Mozambique. The study area was chosen as it typifies the challenge of managing mopane woodlands for the benefit of the rural poor in southern Africa. We find confirmation for the hypothesis that cash income from charcoal production is not a sufficient condition to alleviate acute multidimensional poverty in the study region. Our findings show a high intensity (67.7%) and prevalence of AMP (0.429) in the study area, based on the Alkire-Foster method. Charcoal income is found to be positively correlated with valuable household assets, and charcoal production increases the resistance to impoverishment in certain circumstances. However, charcoal income was not found to be a statistically significant determinant of AMP, even for the most productive charcoal makers. 59% of the identified non-monetary poor from charcoal making are identified as acute multidimensionally poor. This highlights the enormous barriers both producers and non-producers of charcoal alike face in this region in order to overcome multidimensional poverty. Reductions and eventual eliminations of AMP require a concentrated cross-sectional whole-of-government approach to tackle poverty in its multidimensional breadth and complexity, while attempts at making the charcoal industry more inclusive and equitable should be accelerated.

## Conflict of interest statement

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

## Authors' contributions

The lead author was responsible for the overall concept and design

of the paper, as well as the writing of the paper. All authors provided data collection and analysis, and commented on the manuscript. The “percent contribution-indicated” approach (Tscharntke, Hochberg, Rand, Resh, & Krauss, 2007) was used for establishing the authorship order.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.wdp.2017.11.005>.

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